2001-12

Can level of Information Systems Interoperability (LISI) improve DoD C4I Systems' Interoperability?

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http://hdl.handle.net/10945/6207

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

CAN LEVEL OF INFORMATION SYSTEMS INTEROPERABILITY (LISI) IMPROVE DOD C4I SYSTEMS' INTEROPERABILITY?

by

Susan Chiu

December 2001

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REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 2001	Master's Thesis

4. TITLE AND SUBTITLE Can Level of Information Systems Interoperability (LISI) Improve DoD C4I Systems' Interoperability?

5. FUNDING NUMBERS

6. AUTHOR (S) **Susan Chiu**

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the U.S. Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release, distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT ***(maximum 200 words)***

Level of Information System Interoperability (LISI) is a maturity model and interactive process for assessing and improving interoperability. The heart of the LISI concept is the formulation of a system "profile" which was created through the web-based LISI tool, Inspector 1.0. LISI considers five increasing levels of sophistication with respect to exchanging and sharing information and services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction. The increase is expressed in terms of four attributes: *Procedures, Applications, Infrastructure, and Data.* LISI Inspector leverages the data captured in the Inspector Survey to generate four primary sets of assessment products to be as LISI management tool: *Interoperability Profiles, Interoperability Assessment Matrices, Interoperability Comparison Tables*, and *Interoperability System Interface Description*. A principal finding of this research is that LISI has potential to improve DOD C4I systems' interoperability but the current LISI tool has to be refined. Also, LISI must continue to evolve and adopt the dynamic nature of military operations, system acquisition, and technology improvements so LISI can be useful in contributing to the improvement of DOD C4I systems' interoperability and to achieve the Information Superiority envisioned by Joint Vision 2010.

14. SUBJECT TERMS: Level of Information Systems Interoperability (LISI), Overview of LISI, Interoperability, DoD C4I Systems, Interoperability Tool, LISI Tool, LISI Process, Web-based Interoperability Tool, Inspector Survey, Interoperability Improvement

15. NUMBER OF PAGES 105

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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CAN LEVEL OF INFORMATION SYSTEMS INTEROPERABILITY (LISI) IMPROVE DOD C4I SYTEMS' INTEROPERABILITY?

Susan Chiu

M.S., The University of Mississippi, 1973

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN PROGRAM MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
DECEMBER 2001

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ABSTRACT

Level of Information System Interoperability (LISI) is a maturity model and interactive process for assessing and improving interoperability. The heart of the LISI concept is the formulation of a system ”profile” which was created through the web-based LISI tool, Inspector 1.0. LISI considers five increasing levels of sophistication with respect to exchanging and sharing information and services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction. The increase is expressed in terms of four attributes: *Procedures, Applications, Infrastructure, and Data.* LISI Inspector leverages the data captured in the Inspector Survey to generate four primary sets of assessment products to be as LISI management tool: *Interoperability Profiles, Interoperability Assessment Matrices, Interoperability Comparison Tables*, and *Interoperability System Interface Description*. A principal finding of this research is that LISI has potential to improve DOD C4I systems’ interoperability but the current LISI tool has to be refined. Also, LISI must continue to evolve and adopt the dynamic nature of military operations, system acquisition, and technology improvements so LISI can be useful in contributing to the improvement of DOD C4I systems’ interoperability and to achieve the Information Superiority envisioned by Joint Vision 2010.

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ACKNOWLEDGEMENTS

Thank you and thank each of you sincerely:

To Mr. Tony Kunsaitis for his introducing to the wonder world of information system interoperability and for his guidance in capturing the essence of the LISI process

To Mr. Mike Boudreau for his constant encouragement and his clear direction in pursing this thesis research

To Mr. Bruce Thomas and Mr. Randy Stubins for their assistance in providing valuable research material

To Mr. John Horton, Ms. Elaine Christian, Ms. Nita Maniego, and Ms. Nancy Sharrock for their automation support

To my husband, Peter Chiu, for his wonderful moral support and his willingness to evacuate from “his computer room” whenever I need to use the computer at home to do the research and write this thesis

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I. INTRODUCTION

A. PURPOSE

The purpose of this research paper is to investigate whether Levels of Information Systems Interoperability (LISI), a computer software process, can improve Department of Defense (DOD) Command, Control, Communications, Computers, and Intelligence (C4I) systems' interoperability. This is accomplished by researching the development of LISI and analyzing why LISI was implemented, what the elements of LISI capabilities model are, how the LISI process works, and whether it can actually improve the interoperability.

B. BACKGROUND

Command, Control, Communications, Computers, and Intelligence (C4I) systems relay critical information to U.S. forces during joint operations. If joint operations are to be successful, C4I systems must be "interoperable," i.e., capable of exchanging information and operating effectively together. However, the military services have a long history of interoperability problems during joint operations. For example, the success of the Persian Gulf War in 1991, a major joint military operation, was hampered by a lack of basic interoperability. Since then, the DOD has had a number of initiatives to address various aspects of interoperability including Joint Tactical Architecture, Defense Information Infrastructure/Common Operating Environment (DII/COE), DII Master Plan, Shared Data Environment (SHADE), Joint Battle Center (JBC), Joint Interoperability Test Command (JITC).

Commencing in 1993, LISI has continued to advance in capability through several phases. The "Exploratory Phase" in 1994 consisted of an initial assessment for Joint Task Force Operations in support of the Intelligence Systems Council (ISC). During the "Analysis Phase" in 1996, the LISI Maturity Model and assessment process was developed. The "Proof of Concept Phase" in 1997 began to implement the process with an automated prototype and examined the LISI capability through a set of preliminary

tests. During the FY99 "Development Phase," six organizations to include the U. S. Army Program Executive Office, Command, Control, and Communications (PEO C3S) examined and tested the prototype for its utility in assessing and potential for identifying ways of improving interoperability. The 1999 "Development Phase" was accelerated as the result of the U. S. General Accounting Office (GAO) audit report: Joint Military Operations: Weaknesses in DOD's Process for Certifying C4I systems' Interoperability.

My personal interest in the area of information system interoperability started in August 1997 when I joined PEO C3S. As a member of the 1997 inaugural Competitive Development Group (CDG), I was assigned in PEO C3S to commence my three years of cross-functional and leadership training. The fifty-plus mission critical C3S systems under that PEO overwhelmed me after my previous 10 years of program management experience mainly in business and financial management. I often wondered how these systems interoperate and fit into the Army Battle Command Systems (ABCS) to support DOD's First Digital Division (FDD). Even without strong background in the area of information systems, I put down "Interoperability" as my planned thesis consideration on my Naval Postgraduate School application form without any hesitation.

Working in the Horizontal Technology Integration Office (HTIO), PEO C3S, I was privileged to have firsthand information on LISI progress and to have Mr. Tony Kunsaitis as my associate thesis advisor. Tony is the Interoperability Manager for PEO C3S, and this PEO was the first in the Army to be involved in the LISI efforts. Although LISI was initiated in 1993, it is still foreign for the majority of the program management community. My original discussion with Mr. Kunsaitis about this thesis was to concentrate on how useful LISI would be to the Program Managers, and I hoped to convince the Program Managers to choose LISI as their interoperability tool. However, a memo signed by both LTG Peter M. Cuviello and LTG Paul J. Kern to mandate the use of LISI changed my thesis concentration. Since the Program Managers do not have a choice but to use LISI, I believe that it would be more beneficial to research whether using LISI can actually improve the interoperability, and if any improvements of LISI can be made. Therefore, the purpose of this study is to examine whether LISI can improve information systems' interoperability.

C. RESEARCH QUESTIONS

1. Prime Research Question

Can Levels of Information System Interoperability (LISI), a computer software applications and database with associated processes, improve DOD C4I systems' interoperability?

2. Subsidiary Research Questions

1. What is LISI?
2. What are central elements of LISI and associated process?
3. What are the motivations to implement LISI?
4. How does LISI process work?
5. Is the LISI system secured?
6. Is the LISI system user-friendly?
7. Can LISI improve DOD C4I systems' interoperability?

D. SCOPE

There are five factors that have shaped the scope of my thesis. First, I am personally interested in information system interoperability. Second, there are GAO-reported weaknesses in DOD's process for certifying C4I systems' interoperability. Third, MITRE claims that LISI is the only DOD interoperability improvement initiative that can fill in the gaps between all the other initiatives, whether taken individually or collectively. Fourth, a pilot assessment of the LISI has been completed, using components of the Army Battle Command System (ABCS). Last but not least, the use of LISI has become mandatory. Therefore, the scope of the thesis is framed in how LISI can be used and how it can be improved, not whether LISI should be used.

E. METHODOLOGY

After deciding that I would write about information system interoperability, and hearing that LISI could be the solution for interoperability improvement, I started asking Mr. Kunsaitis a lot of questions about interoperability and the details of the LISI progress. I browsed through the LISI report of October 1999 after MITRE completed its pilot assessment of the LISI using data on components of the ABCS. I gained the overall knowledge on what LISI actually is about and what its process and execution involve. I had my thesis originally planned to show how the LISI can help the PMs and hopefully to convince them to use the LISI. When the use of LISI became mandatory, the need to convince the PMs to utilize LISI remains, but I believe that it is more prudent to research if LISI can actually improve interoperability, if any modification of LISI can further improve the interoperability, and not whether LISI should be used.

The MITRE Corporation has been the LISI developer for the Army since 1993. To further support the Army System Engineering Office (ASEO) and Horizontal Technology Integration (HTIO), PEO C3S, MITRE delivered and configured a Prototype server at HTIO, PEO C3S. MITRE conducted a pilot LISI assessment of a selected subset of ABCS components in 1999. In early coordination discussions MITRE concluded that three systems about the complexity of the All Source Analysis System (ASAS) would be a workable analysis for the effort to recommend changes to the data collection capability of LISI. Following that, the assessment of a full set of 10 to 11 ABCS component systems was completed. The LISI data collection (survey) portion of the prototype was developed to collect information about a system through the use of a common web-based browser as the interface. Once the information is entered, the prototype applies the four levels, four parameter LISI paradigm to produce the interoperability profile of a system. This yields a quantitative measure of a system's (or interfaces') interoperability potential. The result of this pilot assessment of the LISI was reported in October 1999 by MITRE.

F. ORGANIZATION OF THE STUDY

Chapter II provides an overview of LISI, its elements, and its associated process. Chapter II also introduces the motivations to implement LISI in term of information systems' interoperability.

Chapter III illustrates how LISI process works by discussing the development and use of the LISI prototype tool in its application to Army Systems. Next it examines the LISI user friendliness and its security.

Chapter IV provides analysis of the primary research question as whether LISI can improve DOD C4I systems' interoperability. The reports from the LISI pilot assessment conducted by MITRE in 1999 and the final analysis assessed by HTIO Interoperability in 2001 were used for the analysis.

Chapter V summarizes the findings of the research, answers the research questions, and presents recommendations for further research and study.

G. BENEFITS OF THE STUDY

It is my hope that this study will be used to continue the evolution, refinement, application, and institutionalization of LISI because applying LISI may benefit the following:

<u>Joint Mission Planners</u> – who need to be able to use LISI in context with mission area assessments to facilitate the development and dissemination of interoperability requirements for new systems.

<u>Program Managers</u> – who need to be able to use LISI to identify potential interoperability problems early in the analysis phase of system development (the period during which implementation choices are made) rather than discovering issues after system fielding.

Command Architects – who need to be able to use LISI to assess the interoperability of systems in an existing or planned architecture, to evaluate alternative strategies, to improve interoperability, and to meet the mission and operational requirements.

Joint Task Force (JTF) Planner – who needs to be able to use LISI to assess the interoperability of existing systems prior to deployment, including the rapid identification and resolution of interoperability shortfalls.

System Evaluators – who need to be able to use LISI during laboratory or field experimentation to determine the impact of various interoperability levels on mission effectiveness.

II. WHAT IS LISI?

A. INTRODUCTION

Although LISI was initiated in 1993, it is still foreign to the majority of the program management community. In order to examine how LISI can improve DOD C4I systems' interoperability, it is prudent to know exactly what LISI means and what its functionalities are and how LISI actually works. This Chapter will exam the "What's" and Chapter III will discuss the "How's." The following sections give a description and background information on LISI, its evolution, its elements, and its benefits of implementation. Also, other DOD Information Technology (IT) initiatives are discussed in relation to LISI.

Much of the information presented in this chapter was extracted and summarized from several information interoperability and LISI related reports and briefings. The reports include GAO report of March 1998 on Joint Military Operations, C4I Surveillance and Reconnaissance (C4ISR) Architectures Working Group Final Report of 14 April 1998, and Pilot Assessment of the LISI Using Components of the ABCS Final Report of November 1999. The briefings include Army LISI Overview Briefings of 12 October 2000 from Department of Army Military Office – Directorate of Integration (DAMO-DOI); Defense Information Systems Agency – Joint C4 Program Assessment Tools (DISA-JCPAT); Office of the Secretary of Defense – Assistant Secretary of Defense Command, Control, Communications and Intelligence (OSD-ASD C3I); and the Army. Detailed information from each of these Army briefings is now available at http://sysarch.army.mil/LISI Inspector/references.

B. LISI DEFINITION AND FUNCTIONALITIES

LISI can be defined as **a formal Reference Model, an assessment implementation of the interoperability maturity model, and a structured process for**

improving interoperability between varied information systems. Simply said, LISI is a maturity model and interactive process for assessing and improving interoperability.

The LISI tool provides an automated, web-based interoperability assessment capability. It provides interoperability analysis, such as interoperability profiles for C4ISR information technology (IT) systems, interface status between systems at nodes or within a mission area, and end-to-end interoperability levels for a specific mission. It is intended to support system of systems interoperability and requirements assessments across the Department of Defense.

By dissecting the above definition and description, the functionalities of LISI can be summarized as: (Levine, 2000)

a. A **discipline** for improving interoperability (It is a formal process.)
b. A **work ethic** for improving interoperability (It requires collective commitment to a process.)
c. A **structured approach** for reaching agreement about what capabilities are needed to improve interoperability (It involves common understanding of how to implement a process.)
d. A **measure of performance** for interoperability that characterizes what capabilities can be performed between systems (It is expressed in "levels" of increasing sophistication.)

However, LISI is **not a prescription** for guaranteeing interoperability. The heart of the LISI concept is the formulation of a system "profile" which was created by LISI. The "profile" may become the common denominator for determining interoperability between C4 systems but it is certainly **not a prescription for guaranteeing interoperability**. The profile is an indicator and not an absolute. The reason is simply that "garbage in and garbage out" and the system can only be as good as the data. The questionnaires used for the process may not be inclusive of **all** pertinent interoperability elements required. Furthermore, the person entering the data for the questionnaires might be not knowledgeable enough to answer all the right questions with the correct answers. Therefore, LISI is a tool to examine, to compare, but not to guarantee the interoperability of IT systems.

C. MOTIVATION OF INITIATING AND IMPLEMENTING LISI

1. Achieve Information Superiority

The Chairman of the Joint Chiefs of Staff advanced a bold vision of American war fighting capabilities, Joint Vision 2010, which has become the conceptual template for how we will channel the vitality of our people and leverage technological opportunities to achieve new levels of effectiveness in joint war fighting. (Shalikashvili, 1997) At the heart of the joint vision is **information superiority –** the ability to collect and distribute to U.S. forces throughout the battlefield an **uninterrupted flow of information**, while denying the enemy's ability to do the same**.** (Cohen, 1997) The Quadrennial Defense Review (QDR) of May 1997 also identified **information superiority** as the backbone of Military Innovation, and noted that the Revolution in Military Affairs (RMA) centers on developing the improved information, and command and control capabilities needed to significantly enhance joint operations.

In order to provide uninterrupted flow of information during the military joint operations, the C4I systems must be "interoperable." Unfortunately, the military services have a long history of interoperability problems during joint operations. LISI was initiated in 1993 after the difficulties of basic interoperability experienced during the Persian Gulf War in 1991. The **information superiority** envisioned by Joint Vision 2010 in 1997 further challenged the development and implementation of LISI.

2. Support Joint Task Force (JTF)

The JTF that fights the next conflict does not exist until the need arises. Its approach to information management and the set of electronic information systems will be based in large part on which Services is in charge of the operation. Though all Services provide their essential set of automated "tools," the particulars of which ones, how many, where they are located, etc. are all dependent on the situation and the decisions of the assigned Service Commander or someone in his chain of command. Determining how these systems are pulled together to accomplish a joint mission is of one of the major challenges facing the development of information system architectures

throughout DOD. Information systems built to meet specific Service requirements must still provide for the appropriate level of C4ISR interoperability to meet joint requirements. Therefore, understanding how much interoperability is required is a key consideration that must be accounted for when designing constructing, and deploying IT architecture.

In order to support JTF, LISI has been designed to focus on defining and assessing systems against increasing levels of sophistication for system-to-system interaction. These levels describe the stages of process improvement for interoperability and are documented in the form of an Interoperability Maturity Model.

3. Compliance With Information Technology Management Reform Act (ITMRA)

The ITMRA of 1996 (Public Law 104-106), also know as the Clinger-Cohen Act, requires the Federal government to develop "a process and procedure for establishing goals for improving the efficiency and effectiveness of government agencies' operations and the ability to deliver goods and services to the public using information technology. The goals must be "measurable." (C4ISR, 1998)

The ITMRA further states that, "the director shall encourage the use of performance-based and results-based management." Before LISI, there were no widely accepted performance-based and results-based standards for interoperability. Now LISI directly supports the development of IT architectures within the context of ITMRA by assessing the level of interoperability required and attained between systems. (C4ISR, 1998)

4. Assist in Certifying Process And Improving C4I systems' Interoperability

GAO identified several weaknesses in DOD's process for certifying C4I systems' interoperability in its March 1998 report. The Joint Staff's Director for C4 systems (J-6) is assigned primary responsibility for ensuring compliance with certification requirement. Certification is intended to help provide the war fighter with C4I systems that are

interoperable and to enable forces to exchange information effectively during a joint mission. However, DOD did not have an effective process for certifying existing, newly developed, and modified C4I systems for interoperability. As a result, many C4I systems have not been certified for interoperability and DOD did not even know how many require certifications. (GAO, 1998)

GAO warned that improving ways of complying with the certification process alone would not solve all of the issues related to interoperability and a number of initiatives had to be continued. LISI was one of the initiatives mentioned in the report. GAO indicated, "DOD's 1993 LISI initiative is to improve C4 and intelligence systems' interoperability. System developers are to use this tool to assess interoperability, determine capabilities needed to support system development, and determine the degree of interoperability needed between C4I and other systems." (GAO, 2000)

5. Become A Mandatory Interoperability Evaluation Tool

In recognizing that the Army lacks a means to quickly assess System-Of-Systems (SoS), the Director of Information Systems for C4 and the Military Deputy to the Assistant Secretary of the Army (Acquisition, Logistics and Technology) mandated on their joint memorandum of 15 August 2000 that the Headquarters of Department of Army (HQDA) to employ LISI framework and its associated interoperability assessment tool to address SoS interoperability.

The memorandum further explained the rational for mandating of implementing LISI. Chairman Joint Chiefs of Staff Instruction, 6212.01B, dated May 8, 2000, calls for the development of the Command, Control, Communications, Computers and Intelligence Support Plan (C4ISP). A C4ISP must be developed for all systems that exchange information in any electronic form. The technical data stored in LISI, along with LISI output products, satisfy the C4ISP requirements for a technical architecture profile and view. Therefore, using LISI to meet this requirement gives the Army a standard, mature process to collect, archive, and share this information. (Cuviello, 2000)

D. EVOLUTION OF LISI

LISI has come a long way to today's pilot assessments and implementation. MITRE Corporation has been the developer of the LISI process and its associated software application since the inception of LISI in 1993. It is a process that has evolved since its inception in 1993. The Intelligence Systems Council (ISC) conducted the initial concept and process. Then Integration Task Force (ITF) expanded and detailed the LISI concept and scope significantly in 1996. During 1997, Architectures Working Group (AWG) conducted the third phase, proof of concept. In 1999, the pilot assessments were conducted and the Initial Operational Capability (IOC) 2000 followed. A snapshot of the evolution is summarized in figure 2-1 below. (DOI, 2000)

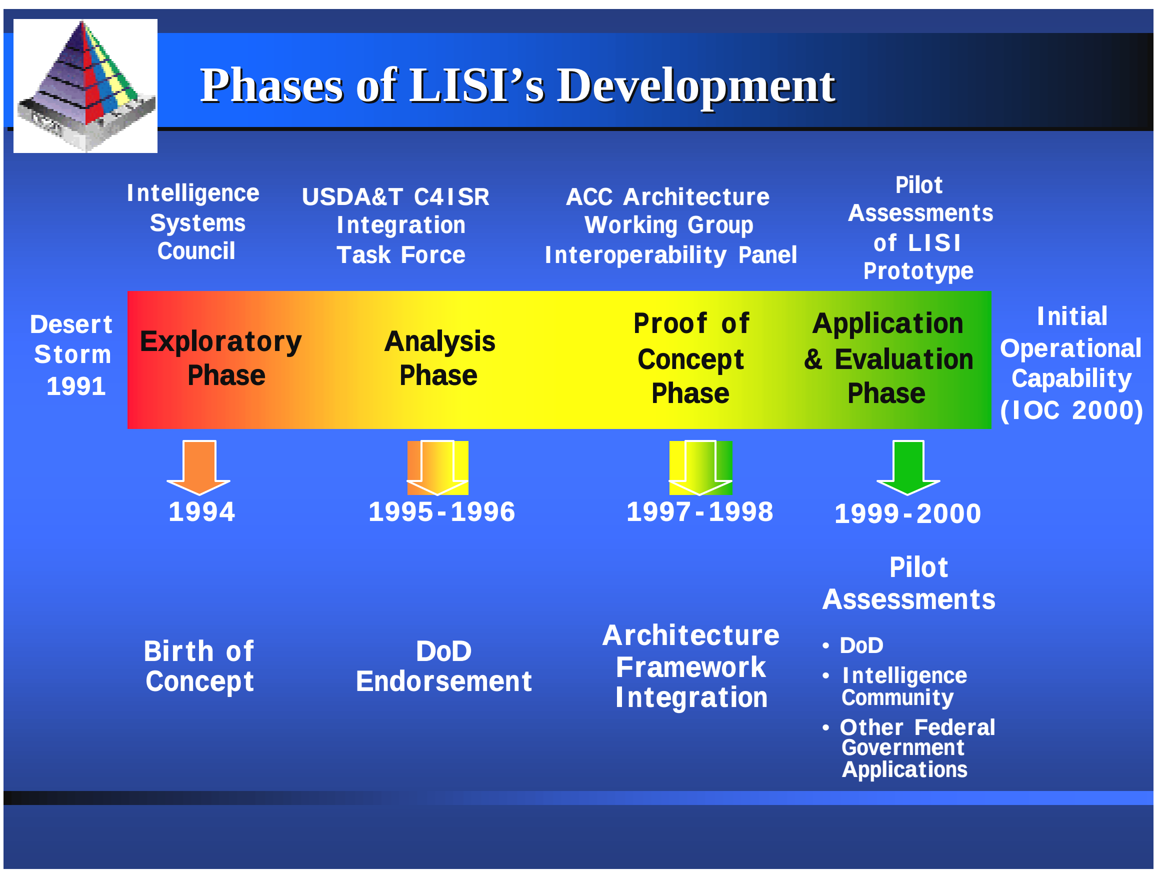

Figure 2-1. Evolution of LISI, from (DOI, 2000)

1. Exploratory Phase, Intelligence Systems Council (ISC), 1994 (Birth of the Concept)

In 1993, the ISC was at the end of its wits. U.S. military force deployments continued to indicate that the automated information systems used by the military departments did not interoperate well, if at all. Individual organizations and program managers had their own interpretations of "interoperability." When consensus could not be reached, the member organizations turned to the formal definition. According to the Joint Publication 1-02, DOD Dictionary of Military and Related Terms, interoperability is defined as follows:

> The condition achieved among communications-electronic systems or items of communications-electronic equipment when information and services can be exchanged directly and satisfactorily between them and/or their users. **The degree of interoperability should be defined when referring to specific cases.** (DOI, 2000)

The ISC participants focused heavily on the last sentence in the DOD definition, and recognized the need to define "**degrees**" or "**levels**" of interoperability that could accomplish the following:

a. Serve to discriminate major variances in required Joint information transactions and sophistication from one system to another.
b. Provide for a simple construct to facilitate cross-organizational coordination.
c. Enable interoperability assessments of intelligence and Command and Control (C2) systems that need to interact.
d. Serve to guide or discipline interoperability improvement actions. (DOI, 2000)

2. Analysis Phase, C4ISR ITF, 1995-1996 (DOD Endorsement)

In October 1995, the Deputy Secretary of Defense tasked (ASD) (C3I) to define and develop better means and processes to ensure C4I capabilities most effectively meet the needs of our warfighters. In response to this tasking, the C4ISR ITF was established and an Integrated Architectures Panel (IAP) was created to engineer a C4ISR architecture process and identify ways to improve systems interoperability. The IAP advocated the

concept of “Level of Interoperability” as mechanism for C4ISR practitioners to negotiate an affordable and technically appropriate capability mix among C4ISR systems intended to interoperate, and to ensure Joint interoperability. Finally, The Under Secretary of Defense Acquisition and Technology (USDA&T), the Assistant Secretary of Defense (ASD) (C3I), and Vice Chairman of the Joint Chiefs of Staff (VCJCS), endorsed the levels of interoperability concept and tasked the ASD (C3I) to lead a follow-on effort to “define and use Levels of interoperability” (DOI, 2000)

3. Proof of Concept Phase, C4ISR AWG, 1997-1998 (Architectural Framework Integration)

Building upon the recommendations of the C4ISR ITF and the LISI report published in June 1996, MITRE Corporation was tasked to continue to work with the C4ISR community to further evolve LISI. In an effort to engage DOD community participation, an Interoperability Panel was formed in January 1997 as part of the C4ISR AWG sponsored jointly by the ASD (C3I) and the Joint Staff (JS) J-6. (DOI, 2000)

4. Application And Evaluation Phase, DOD, 1999-2000 (Pilot Assessments)

At the request of the Army Systems Engineering Office with coordination of the Horizontal Technology Integration Office, PEO C3S, MITRE undertook the pilot assessment of LISI. In November 1999, MITRE published their pilot assessment report of the LISI using components of the ABCS. This report discussed the development and use of the LISI prototype tool in its application to Army Systems. Software development questionnaire building and prototype installation are described. Then the prototype’s utility is discussed through its application to the Army’ ABCS 4.0 component systems. (DOI, 2000)

5. Initial Operational Capability (IOC), DOD, 2000-present (IOC 2000)

DOI hosted a kickoff meeting and provided training on the LISI tool in October 2000 in response to Lieutenant General Peter M. Cuviello and Lieutenant General Paul J.

Kern's memorandum directing the mandatory use of LISI. The IOC participation includes Army Materiel Command (AMC) soldier & Biological Chemical Command (BCC), AMC Tank Automotive Command (TACOM), PEO Aviation, PEO Standard Army Management Information System (STAMIS), and PEO Theater Missile (TM). (DOI, 2000)

However, the LISI is a living entity and will be constantly evolving. In concert with technological advances in information systems and changes in the methods by which enterprises employ information systems technology in support of their operations, the continuing evolving of the LISI is anticipated.

E. THE ELEMENTS OF LISI CAPABILITIES MODEL

In order to evaluate whether the LISI can improve IT interpretabilities, the understanding of the planned LISI Capabilities Model is essential. A capabilities model, such as that defined within LISI, is commonly described as a set of concepts, entities, interfaces, and diagrams that provides common ground for understanding and comparisons. It does not provide a specific system design or prescription for implementation, but it does define a common set of services and interfaces for building specific designs. In a similar manner, the LISI Capabilities Model does not prescribe specific implementation choices necessary to attain a level of interoperability. Instead, LISI draws heavily from commonly existing organizational directives and mandates. In the case of DOD, these implementation choices are derived from related sources such as the Joint Technical Architecture (JTA), Defense Information Infrastructure (DII) Common Operating Environment (COE), and Shared Data Environment (SHADE).

LISI Capabilities Model

Figure 2-2, from (OSD, 2000)

LEVEL (Environment)			Interoperability Attributes: P	A	I	D
Enterprise Level (Universal)	4	c	Multi-National Enterprises	Interactive (cross applications)	Multi-Dimensional Topologies	Cross-Enterprise
		b	Cross Government			
		a	Govt Enterprise	Full Object Cut & Paste		Enterprise Model
Domain Level (Integrated	3	c	Domain Organization-wide Doctrine, Procedures, Training, etc.	Shared Data (e.g., Situation Displays	WAN	DBMS
		b		Group Collaboration (e.g.,White		Domain Models
		a		Full Text Cut & Paste		
Functional Level (Distributed)	2	c	Common Operating Environment	Web Browser	LAN	Program Models & Advanced Data Formats
		b		Basic Operations Documents Briefings Pictures & Maps Spreadsheets Databases		
		a	Program Standard Procedures, Training, etc.	Adv. Messaging Message Parsers E-Mail	NET	
Connected Level (Peer-to-Peer)	1	d	Standards Compliant	Basic Messaging (e.g.,Formatted Text, E-mail w/o attachments)	Two Way	Basic Data Formats
		c		Unformatted		
		b	Security Profile	Data File		
		a		Simple Interaction (e.g., Remote, Chatter,	One Way	
Isolated Level (Manual)	0	d	Media Exchange	N/A	Removable Media	Media
		c	Collocated systems, Single operator		Manual Re-entry	Private Data
		b	Collocated systems, Separate operators			
		a	Non-collocated systems, Exchange via Operators			
		o	NO KNOWN			

1. The “Level” Concept

a. Level 0: Isolated (Stand Alone)

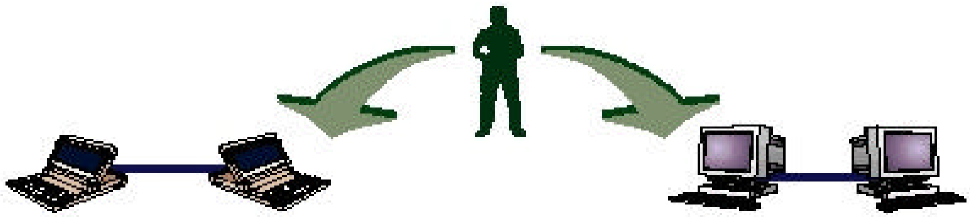

Figure 2-3. Level 0: Isolated Interoperability in a Manual Environment, from (C4ISR, 1998)

Figure 2-3 represents Level-0 interoperability. Level 0 is described as isolated interoperability in a manual environment. The key feature of Level 0 is human intervention to provide interoperability where systems are isolated from each other. Level-0 systems need to exchange data or services, but cannot directly interoperate. The lack of direct, electronic connectivity may exist solely due to differing security or access – control policies, or it may be a lack of physical connection between two systems. (C4ISR, 1998)

b. Connected (Peer to Peer)

Figure 2-4. Level 1: Connected Interoperability in a Peer-to-Peer Environment, from (C4ISR, 1998)

Figure 2-4 represents LISI Level-1 interoperability. Level 1 is described as connected interoperability in a peer-to-peer environment. The key feature of Level 1

is physical connectivity providing direct interaction between systems. Level 1 systems have an established electronic link characterized by separate peer-to-peer connections. At this level of interoperability, the interactions are between discrete systems. Links can locally support simple file exchanges between systems. The type of files exchanged is typically homogeneous in context (e.g., text-only file, a bitmap file). (C4ISR, 1998)

c. Distributed (Functional)

Figure 2-5. Level 2: Functional Interoperability in Distributed Environment, from (C4ISR, 1998)

Figure 2-5 represents Level-2 interoperability. Level 2 is described as functional interoperability in a distributed environment. The key feature of Level 2 is the ability of independent applications to exchange and use independent data components in a direct or distributed manner among systems. Level-2 systems must be able to exchange and process complex (i.e., heterogeneous) files. These files consist of items such as annotated images, maps with overlays, and multi-media or hyper-linked documents. The systems are generally connected to multiple systems on local networks. A key capability provided by systems or applications, at the top end of this level, is the ability to enable and provide web-based access to data. (C4ISR, 1998)

d. *Integrated (Domain)*

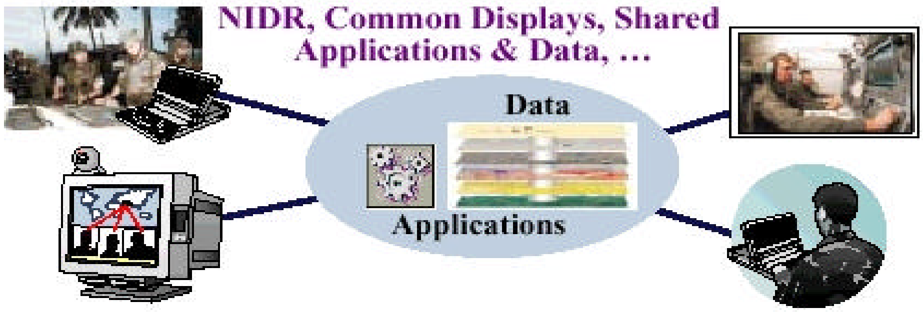

Figure 2-6. Level 3: Domain Interoperability in an Integrated Environment, from (C4ISR, 1998)

Figure 2-6 represents Level-3 interoperability. Level 3 is described as domain interoperability in an integrated environment. The key feature of Level 3 is a domain perspective that includes domain data models and procedures where data is shared among the independent applications that may begin to work together in an integrated fashion. Level 3 is characterized by multiple application-to-application interactions. Systems and applications are interconnected, but generally operate on a single functional set of data (e.g., intelligence, C2, logistics). Implementation at this level usually has only a localized view of the distributed information space and cross only one operational or functional domain. (C4ISR, 1998)

e. Networked (Enterprise)

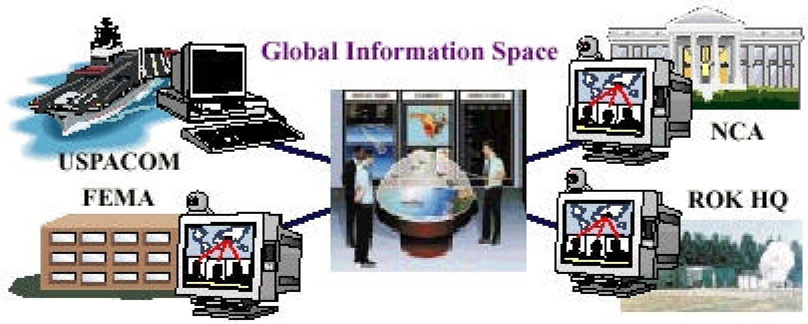

Figure 2-7. Level 4: Enterprise Interoperability in a Universal Environment, from (C4ISR, 1998)

Figure 2-7 presents Level 4 interoperability. Level 4 interoperability is described as enterprise interoperability in a universal environment. The key feature of Level 4 is a top-level perspective that includes enterprise data models and procedures, where data is seamlessly shared among the applications that work together across domains in a universal access environment. Level 4 is the ultimate goal of information systems seeking interoperability across functional activities and informational domains (e.g., Intelligence, C2, and Logistics). At this enterprise level, information is shared globally through distributed information architecture. Applications and systems operate as necessary across all the functional data domains. The 'virtual' workspace uses shared applications operating against an integrated information space. Level 4 represents the capabilities necessary to achieve concepts proposed in DOD's Joint Vision 2010 documents. (C4ISR, 1998)

2. The "Attributes" – PAID

LISI categorizes the various aspects of information systems interoperability in terms of four comprehensive, closely interrelated attributes: **Procedures**, **Applications**, **Infrastructure**, and **Data** (PAID). They are the enablers of interoperability and its various maturity levels. Individually, these attributes are like pieces of a puzzle, each

possessing its own identity (shape) and purpose (content). When joined together (pictured in Figure 2-8), these attributes can be represented as a complete circle whose "circumference" encompasses the entire realm of interoperability issues and considerations and whose "area' defines the full set of conditions, characteristics, and criteria necessary for achieving interoperable environments. Consideration and understanding of the interrelationships between all the PAID attributes are critical for moving interoperability beyond the simple connection between systems. In order to assess interoperability completely, it is necessary to apply PAID throughout each of the levels described in section 2.5.1.

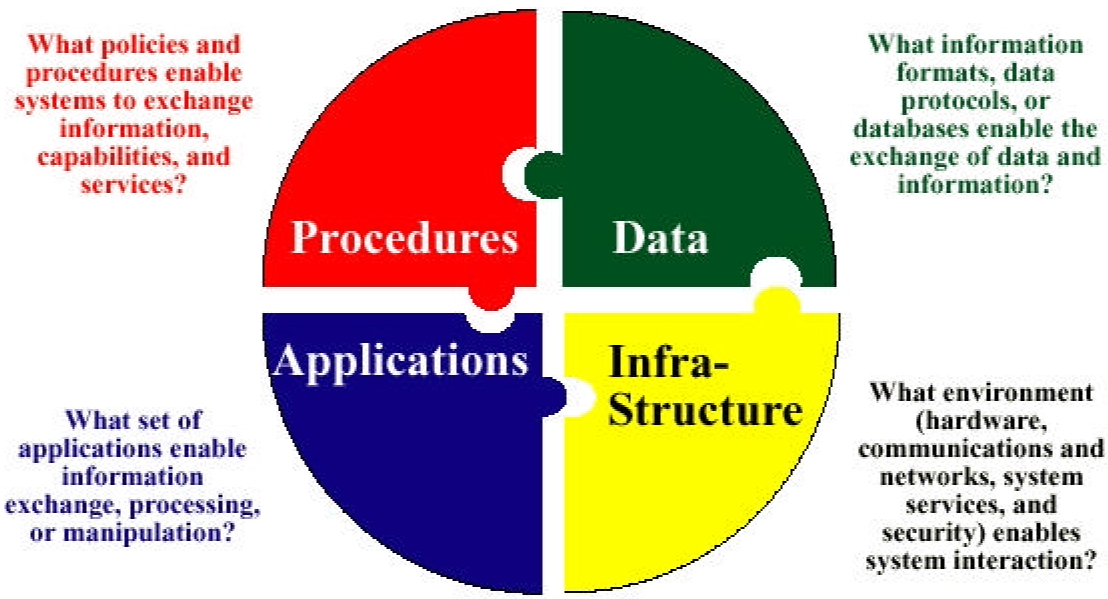

Figure 2-8. The PAID Attributes, from (Levine, 2000)

a. Procedures

It encompasses the many forms of documented guidance and operational controls that affect all aspects of system development, integration, and operational functionality. This attribute addresses specific implementation options selected for a system or systems as well as overarching standards and architecture guidance for the given enterprise. It encompasses operational and functional program development guidance as well as technical and system architecture standards (such as hardware, system software, communications data, and applications). Items that make up the

procedures attribute are organized into four major categories that span the levels of interoperability

a. Standards: Technical Standards, Technical Architectures, and Common Operating Environment (COE)
b. Management: Mission, Doctrine, Systems Requirement Definitions, Installation, and Training
c. Security Policy: Classified, Unclassified, or Secret
d. Operations: Network, E-Mail Servicing, and Bandwidth Considerations (C4ISR, 1998)

b. Applications

It encompasses the fundamental purpose and function for which any system is built, that is, its mission. The functional requirements specified by users to perform an operational activity are the very essence of the software application. Whether it is the need to do simple word processing or perform advanced nuclear targeting, the functions being accomplished and the *applications* that support them represent the system's capabilities to the user. For interoperability to occur effectively, similar capabilities or a common understanding of the shared information must exist between systems; otherwise, users have no common frame of reference. (C4ISR, 1998)

c. Infrastructure

It supports the establishment and use of a "connection" between systems or applications. This connection may be a simple, extremely low-level exchange, or it could consist of wireless Internet Protocol (IP) networks, operating at multiple security levels. These two examples point out the breadth of the communications and hardware aspects. *Infrastructure* also includes "system services" that facilitate systems operations and interactions. These are items such as communication protocol stacks and object request brokers that are used by functions to establish and affect interactions between systems. The security devices and technical capabilities that are used to implement security procedures also make up a part of *infrastructure*. (C4ISR, 1998)

d. Data

It focuses on the information processed by the system. This attribute deals with both the data format (syntax) and its content or meaning (semantics). It includes all the forms of data that support every level of a system's operations, which is from its operating system and communications infrastructure to the full set of end-user applications. The *data* attribute embodies the entire range of information styles and formats: free text, formatted text, databases (formal and informal), video, sound, imagery, graphical (map) information, etc. As such the *data* attribute is understandably the most critical aspect of attaining systems interoperability. It is within this attribute where much of today's focus and work towards building interoperable systems is taking place, such as defining standard file formats, standards of databases, and data definitions. (C4ISR, 1998)

F. LISI AND DOD IT INITIATIVES

There are numerous DOD initiatives that are focused on one or more aspects of interoperability. Each initiative lends an important contribution to the process of improving interoperability. What is lacking is a way to pull all of these together to give meaning to statements about interoperability. LISI is the key tying it all together, using a uniform capability-model structure and discipline, and a comprehensive coverage of all key aspects of the **PAID** attributes as discussed in section 2.5.2. LISI works to track these initiatives and their associated constructs, interrelate them using the family of LISI models, leverage their findings and positions into the LISI assessment process, and provide the integrated basis for coordinating these initiatives to maintain consistency and currency. The examples of how LISI integrates and interrelates to these DOD initiatives are summarized in the following. (C4ISR, 1998)

1. Joint Technical Architecture (JTA)

JTA Standards ***LISI***

JTA Component	Function (JTA Reference)	JTA Paragraph	Description (Capabilities)	Technical Profile	LISI Attribute (PAID)	LISI Level	LISI Question
HCI	User Interface Services	2.2.2.1.2	Window Environment - CDE version 1.0 based on X Window and OSF Motif **AND**	FIPS 158-1	I	2b	
			Window Environment - CDE version 1.0 based on X Window and OSF Motif **AND**	OSF Motif AES, Release 1.2	I	2b	
			Window Environment - CDE version 1.0 based on X Window and OSF Motif **AND**	OSF/Motif ICCCM for GUI clients	I	2b	
			Window Environment - CDE version 1.0 based on X Window and OSF Motif **OR**	X/Open C323, CDE version 1.0	I	2b	
			Window Environment - Native Win32 for NT 3.5.1	Win32 APIs, Window Mgt and Graphics Device Interface	I	2b	
Data Management Services - 2.2.2.1.3	Data Management Services	2.2.2.1.3	Database Language for Relational DBMS (SQL) **AND**	FIPS 127-2 (SQL)	D		
Data Interchange Services - 2.2.2.1.4	Document Interchange	2.2.2.1.4.1	Open Database Co[illegible] Produ[illegible]	ODBC			

Figure 2-9 Cross Mapping of JTA and LISI, from (C4ISR, 1998)

The JTA has been explicitly incorporated into the LISI process. Figure 2-9 presents an extract from the detailed mapping of LISI and the JTA. The LISI Capabilities Model includes the relevant standards from the JTA. Those PAID capabilities and implementations of each LISI-assessed system or application that comply with JTA standards are identified as such in the system's Interoperability Profile. Each entry in the LISI Options Tables that is also in the JTA is identified as such. Therefore, LISI can identify which implementation of any system or application conforms to JTA standards and which implementations are outside the accepted standards found within the JTA. (C4ISR, 1998)

2. Defense Information Infrastructure (DII) Common Operating Environment (COE)

Although LISI and DII COE differ significantly in terms of purpose and scope, they are complementary initiatives. The DII COE focuses on the portability of software and the configuration management of application-to-operating environment interactions

and LISI focuses on the system-to-system interactions that characterize interoperability. However, twenty percent of the DII COE Integration and Runtime Standards (I&RTS) Compliance Checklist questions map directly into LISI. These questions relate to topics such as infrastructure implementations, applications, security issues, and naming conventions. Figure 2-10 presents a portion of the complete DII-to-LISI crosswalk table in order to demonstrate the mapping process. (C4ISR, 1998)

COE Compliance Questions		***LISI***					
COE Level and Section	Runtime Compliance Assessment Question	LISI Y/N/P	LISI (PAID)	LISI Level 1	In Matrix	LISI Question	Reason Not in LISI (Other Issue)
COE LEVEL 1 *Standards Compliance*							
Standards Compliance	1-1 (NT) Hardware components are Windows NT-compliant as defined by the Microsoft document Microsoft Windows NT Hardware Compatibility List #4094.	P					Portability
Operating System	1-2 The operating system and associated software conform to the following standards from the JTA:	P					Portability
	(a) ISO 9445-1:1996, Information Technology - Portable Operating System Interface for Computer Environment (POSIX) - Part 1: System Application Program Interface (API) [C Language], as profiled by FIPS 151-2:1994.	P					Portability
	(b) IEEE 1003.1g:1996 Draft, POSIX - Part 1: System Application Program Interface (API) Amendment 2: Protocol Independent Interfaces (Sockets) [C Language].	P					Portability
	1-3 Unless approved by the DII COE Chief Engineer, the operating system supports the System API for FIPS 119 (Ada95).	N					Portability
	1-4 The operating system is configured to support **DCE** .	Y	I	4a	N	N	
	1-5 The operating system is configured to support **TCP/IP** protocols.	Y	I	2c	Y	Y	
	1-6 The operating system is configured to	Y	I	2c	N		

Figure 2-10. Cross-Mapping of DII COE and LISI, from (C4ISR, 1998)

3. DII Master Plan

The DII Master Plan is a broad document meant to insure that an infrastructure is in place within the DOD to allow for the establishment of a common link between systems as they develop. The ability of systems to work within the Information Infrastructure defined by this plan is critical to ensuring interoperability. Therefore, initiatives focused on implementation of the DII Master Plan should be closely coordinated with LISI. In particular, the way that LISI captures the various aspects of the infrastructure that are included within the scope of the DII Master Plan on a "level-by-

level" basis should be closely synchronized with Master Plan implementation planning efforts.

4. Shared Data Environment (SHADE)

SHADE is representative of the effort within the DOD C4ISR community to reach agreement on common data models for systems. It is a fairly recent initiative, and is not currently as well defined as the DII COE. The SHADE effort is critical to defining those aspects of data needed for interoperability maturity. A preliminary review of SHADE was performed to determine that the LISI process, especially the data attribute of **PAID**, is consistent with SHADE's direction. LISI does not attempt to define data models, but merely records their usage. Deliberate and continuous coordination must be conducted to ensure that LISI and SHADE are tightly integrated as they both evolve. (C4ISR, 1998

5. Joint Battle Center (JBC)

Maintaining the currency of capabilities and implementation captured by LISI is critical as technical standards continue to evolve and as commercial industry continues to release new technologies. The LISI options tables that identify the numerous alternatives available for implementing the general capabilities profiled in the LISI Capabilities Model must be continuously updated. This update process must be performed in close coordination with the operational user community, industry, and the acquisition community. The JBC is an organization where many of these groups come together to examine system performance and interoperability in context with Joint Task Force (JTF) mission operations. The collective insight these groups bring makes the JBC an ideal forum for capturing these integrated views using the LISI construct and process. (C4ISR, 1998)

6. Joint Interoperability Test Command (JITC)

The JITC is faced with the daunting task of testing and certifying DOD information systems. The sheer number of systems makes it impractical to test every possible system-to-system combination. By looking at products produced by LISI, particularly

the various system interoperability profiles, critical interfaces between systems can be identified. The LISI products, in conjunction with architecture information and JBC experimentation results, serve a ‘screening” function in pinpointing what specific aspects of system-to-system interoperability are most critical or most at-risk. These are the areas where testing of systems should focus, where compliance and surety are most important, and where testing will yield a high payoff. The JITC could use the results of LISI assessments to build Test and Evaluation master Plans (TEMPs). These plans will be able to validate the particular implementations that are most critical to interoperability with other systems. (C4ISR, 1998)

G. BENEFITS OF IMPLEMENTING LISI

Before LISI, there was no widely accepted performance-based or results-based standard for interoperability. Now LISI directly supports the development of IT architectures within the context of ITMRA by assessing the level of interoperability required and attained between systems. In addition to being able to tie all DOD IT initiatives together, using a uniform capability-model structure and discipline, and a comprehensive coverage of all key aspects of the PAID attributes, several benefits of implementing LISI can be identified as the following. (AWG, 1998)

1. Quantify Interoperability

LISI revokes the ambiguity in determining levels of interoperability. In addition to an overall rating, LISI measures interoperability along each of its four axes, PAID, and provides the manager with a formal scorecard for interoperability through the common reference model. The LISI model identifies the stages through which systems should logically progress, or “mature’, in order to improve their capabilities to interoperate. LISI also considers five increasing levels of sophistication regarding system interaction and the ability of the system to exchange and share information services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-

to-system interaction. By quantifying interoperability, LISI provides a common DOD basis for requirements definition and for incremental system improvements.

2. Aid in Establishment of Appropriate Level of Interoperability

LISI saves managers money. Not all projects require the same level of interoperability. By establishing a common set of definitions and operating assumptions about interoperability, LISI allows decision-makers to specify appropriate levels of interoperability. A squad level communication device has fewer requirements for interoperability than does a national level collection and processing center, but without some way of specifying an appropriate level, the manager is left trying to guess and he/she perhaps overestimates the level of interoperability.

3. Provide Fully Integrated View

LISI looks at the entire program to include policies and procedures for system implementation. It is not limited to the technical view.

4. Track Interoperability Level Throughout Life Cycle

LISI helps programs throughout their lifecycles. During the design phase, LISI helps managers identify gaps in interoperability between proposed and existing systems. Managers can use the LISI "scorecard" to track their project's interoperability level throughout system development. LISI suggests economical fixes for interoperability gaps.

5. Serve As Management Tool

LISI will benefit all communities from the Program Managers (PMs) to assessment and oversight bodies. The LISI interoperability assessment process provides expedient and collaborative mechanisms and common metrics for DOD to assess current interoperability postures, to identify quick-fix options, to develop strategies for achieving higher states of interoperability maturity, and for providing timely feedback to DOD standards bodies.

The joint mission planners can use LISI in context with mission area assessments to facilitate the development and dissemination of interoperability requirements for new systems. The PMs can use LISI to identify potential interoperability problems early in the analysis phase of system development rather than discover issues after system fielding. Also, the command architects can use LISI to assess the interoperability of systems in an existing or planned architecture and evaluate alternative strategies to improve interoperability to meet the mission and operational requirements.

H. CHAPTER SUMMARY

LISI is a maturity model and interactive process for assessing and improving interoperability. It is a discipline, a work ethic, a structured approach, and a measure of performance for improving interoperability but it **is not a prescription** for guaranteeing interoperability.

LISI was initiated in 1993 because the military services have a long history of interoperability problems during joint operations. The motivations for LISI to continue for developing, prototyping, and implementing are multifaceted. To name a few, the motivations are to achieve information superiority, to support JTF, to comply with ITMRA, to assist in the certifying process and improving C4I systems' interoperability, to implement GAO recommendations, and to become a mandatory interoperability assessment tool.

The "Levels" and the "Attributes" are the essential elements of LISI. LISI considers five increasing levels of sophistication with respect to exchanging and sharing information and services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction. This increase is expressed in terms of PAID – the **Procedures** imposed by information management, the capabilities of **Applications** that act on that data, the type of **Infrastructure** required, and the nature of **Data** transferred.

There are several DOD initiatives to improve information interoperability, why LISI? Evidently, LISI is the key tying all the initiatives all together using a uniform

capability-model structure and discipline, and a comprehensive coverage of all key aspects of the PAID attributes. In addition, LISI will benefit the joint mission planners, the program managers, command architects, and all information system communities to establish an appropriate level of interoperability, to quantify interoperability, to assess, and to improve system interoperability.

III. HOW DOES LISI PROCESS WORK?

A. INTRODUCTION

A web-based tool, Inspector 1.0, has been used to support the interoperability assessment that the LISI system provides. As discussed in chapter II, LISI is a maturity model and interactive process for assessing and improving interoperability. The Inspector has been developed to provide such processes as determining interoperability needs, assessing the ability of specific information systems to meet those needs, and selecting pragmatic solutions and transition paths for achieving higher states of capability and interoperability.

Inspector receives inputs via a system survey questionnaire. The LISI survey contains a questionnaire that can be completed through a web interface to capture relevant data about a system. The tool then performs the mapping of the capabilities against the model, and calculates the resulting profile and level. Users register system characteristics by selecting the appropriate responses to the questions. Questionnaire responses are directly shared within the database and stored in a table from which data can be used to create a set of products (outputs). Hopefully, the interoperability managers can use the LISI reports to identify gaps, shortfalls, and improvement strategies and agreements of system interoperability.

The access to the LISI Inspector is password controlled and the data privacy in the LISI Inspector is highly protected. The first step in registering a system is to acquire a user account from the System Administrator (SA). The LISI tool is web based and is intended to be user friendly. It completed a series of major enhancements during FY 99 that resulted in several incremental "versions," each representing a major increase in either software performance and /or a significant expansion/enhancement of the survey questionnaire. Inspector currently contains approximately 220 questions covering a wide range of topics. These questions now contain over 3,000 possible answers that are currently composed of over 12,000 individual response fields. (MITRE, August 2000)

How LISI works through Inspector will be discussed in more detail throughout this chapter. A capsule view of LISI can be depicted as the following, figure 3-1.

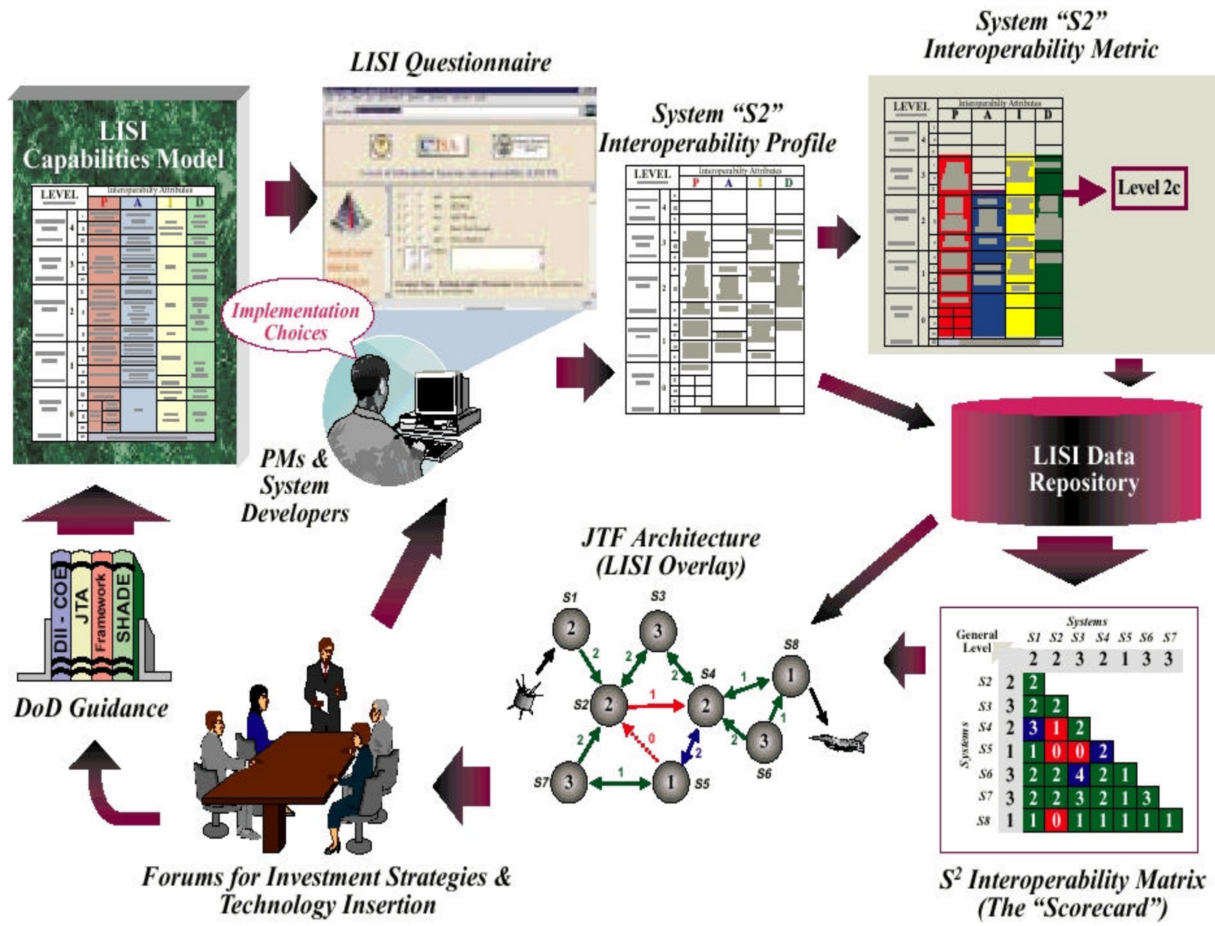

Figure 3-1. A Capsule View of the LISI Assessment Process, from (MITRE, August 2000)

B. LISI TOOL – INSPECTOR 1.0

Inspector 1.0 is a web-based tool for capturing, manipulating, and analyzing information technology (IT) system characteristics in context with any x-y coordinate-based reference model. In addition to DII COE Runtime Environment Compliance Levels and International Standard Organization –Open Systems Interconnection (ISO-

OSI) Protocol Stacks, LISI Capabilities Model is one of the reference models that Inspector 1.0 processes.

Inspector receives inputs via a system survey questionnaire. Questionnaire responses are directly shared within the database. As a result, data being entered into any of the specific surveys (e.g., LISI) is automatically entered into the other surveys (e.g., DII COE, OSI). Inspector also provides the ability to import and export data. Data extracts are constructed as comma-delimited text files that can be sent using most standard email programs.

In order to decide whether LISI can improve interoperability, it is important to understand what its tool is all about and how the tool works. A brief overview of Inspector 1.0 will be examined in term of its evolution, functionality, hardware and software requirements, and access procedures as follows.

1. Inspector 1.0 Evolution – Software Enhancements and Questionnaire Revisions

Inspector 1.0 includes five system surveys, 1) LISI survey, 2) DII COE Integration and Runtime Standards (I&RTS) version 3.1 Survey, 3) DII COE I&RTS version 4.0 Survey, 4) Open Systems Interconnection (OSI) Survey, and 5) US Message Text Format (USMTF) Functional Survey. Each survey has its own structure and question set. Both Versions 3.1 and 4.0 DIICOE Surveys cover the 12-to-13 functional areas identified in I&RTS versions. The OSI Survey contains a structure based on the OSI Reference Model (including major protocol suites). The USMTF Functional Survey covers each USMTF functional area. The LISI Survey focuses on the four interoperability attributes: *Procedures, Applications, Infrastructure*, and *Data.*

Inspector's evolution from a prototype to an operational capability has been driven primarily by expansion of the LISI Survey. The DII COE and the OSI Survey are both relatively new items. The USMTF Survey is a restructuring of USMTF messages by functional area (they are listed in the LISI Survey by USMTF message number). In all cases where a response option is common to questions in multiple surveys, when that response is checked in one survey, it will automatically be checked in all other applicable

surveys. The OSI, USMTF, and some of the DII COE Surveys contain questions with response options in common with each other and with the LISI Survey. (MITRE, August 2000)

2. Inspector 1.0 Functional Components

Inspector provides functionality in several key areas, including database management, user input of system data, customization and use of the survey questionnaire, and output and presentation of reports for comparative analysis of the system data. Inspector provides a database management environment to manage information concerning both the systems being evaluated and the information contained within the questionnaires and their relationships to the x-y coordinate-based reference models, such as LISI Reference Model. The system information includes administrative data such as system name, organization, point of contact, and version. It also includes a compilation of the interoperability characteristics of each system as captured through use of the system surveys. (MITRE, August 2000) The Inspector's major functional components are:

a. Survey Questionnaire

It is the survey interface portion of Inspector that allows users to input information describing their systems through a questionnaire.

b. Multiple Survey Capability

The data calls can exploit the existing data since Inspector is configured to provide credit for a single answer across all appropriate questionnaires.

c. Reports

Inspector generates reports that reflect the information describing the systems.

d. Questions Builder

Inspector currently provides a means for creating new questions through the use of an administrative tool built to operate within a standard web-browser.

e. Data Exchange

With the delivery of Inspector 1.0, organizations are able to import and export system data using a common process. If this integration is accomplished, the information about IT systems can then be easily transported between Services and Agencies using standard Inspector database extracts.

3. Inspector 1.0 Hardware and Software Configurations

Certain hardware and software configurations are required for installation and operational use of Inspector. According to MITRE Corporation, in its Inspector Version 1.0 Description of August 2000, the following components and services must be installed before Inspector can operate correctly:

a. Hardware

Although Inspector can be successfully operated on less capable hardware system configurations, the software demands of Windows NT/Server and the Cold Fusion Server are likely to result in unsatisfactory performance. The recommended hardware configuration is:

- 400 MHz Pentium Processor
- 256 Mbs RAM (512 Mbs recommended)
- 500 Mbs+ free space
- CD-ROM or ZIP drive available to the server

b. Software

Presently, Inspector has been verified and configured for Beta testing on only one operating system. The Inspector software was written in a 4GL that is already

compatible with many other Unix environments but verification testing has not been conducted. The current validated operating systems are Windows NT Workstation or Server 4.0 Service Pack 4 or higher.

Some commercial software packages are needed in order for the Inspector software to function such as Cold Fusion 4.0 Server (Allaire Corp, http://www.allaire.com) and a Web Server compatible with Cold Fusion (Microsoft IIS 4.0 or Peer Server and Personal Web Server, Netscape Enterprise and FastTrack Servers, Apache). The minimum versions of useable web browsers that are verified to work properly with Inspector are Netscape 4.0+ or Microsoft Internet Explorer 4.0+. However, the Netscape 4.0+ is the more reliable browser since Microsoft Internet Explorer 4.01+ has known problems such as timeout errors during report generation.

One of the capabilities provided within Inspector is an ability to produce an extract and perform an automated update of architecture diagrams for import and use in NetViz (soon to Aperture, an optional commercial software package that have been certified). These products are only available at present for Microsoft Windows-95+ configured machines. Currently, individual workstation licenses are required for operating these applications.

4. Inspector 1.0 Access Procedures

The following are the steps for accessing Inspector 1.0 to review and enter system data:

Step 1. Access the web site: http://sysarch.army.mil/LISI/Inspector.

Step 2. Enter system's user-id, its password, and its domain name. The System Administrator (SA) authorizes the password.

Step 3. Highlight the desired survey in the choice box, then press the "Select Survey" button on the bottom of the page.

Step 4. To review & update a system survey, "click" on the "Update" text.

Step 5. No special action is required on the "Inspector Search page" simply press the "Search" button at the bottom.

Step 6. Use the mouse to "click" on the specific system you are authorized to edit. Use the scroll bar on the right to pan down. Once a system has been selected, press the "Access Data" button at the bottom of the page.

Step 7. The REGISTRATION DATA page for the system should now be showing. The frame on the left side of the browser holds a set of buttons used to access various portions of the data contained within a survey. Update the registration page and use the "Submit" button at the bottom of the page. If the Submit button is not showing, you do not have the proper access to edit this system and you need to contact the system administrator to report the problem.

Step 8. Inspector now presents the top-level questions for the survey selected by the user. Answer each question by "clicking" the appropriate item and/or making text entries. After reviewing and modifying as necessary any check-boxes or typed in text, press the "Submit Question Data" button at the bottom. A "next" group of questions that are driven by the first responses will automatically be presented each time the "submit" button is pressed if more questions apply. When the last questions within the survey have been answered, a 'Thank you" page will show on the right frame. The left frame of each survey page provides buttons that allow the user to access specific "Categories" of question.

Step 9. Repeat step 8 for all applicable question sets, one at a time, until the "thank" page for each appears.

Step 10. Send an email to SA when the data review and update have been completed.

C. LISI INPUT

1. LISI Data Collection

Inspector receives inputs via a system survey questionnaire that forms the bridge between the LISI assessment basis and the LISI assessment process and products. LISI uses the Interoperability Questionnaire to collect the pertinent information required to assess information systems interoperability. Because the questionnaire is linked to the LISI models and tables that comprise the assessment basis, the questionnaire covers all of

the different implementation choices and characteristics currently defined in the Options Tables for the capabilities described within the LISI Capabilities Model. (C4ISR, 1998)

Users register system characteristics by selecting the appropriate responses to the questions. Answers are stored in a table from which data can be used to create a set of reports. Questionnaire data is maintained in a "meta-data" format eliminating the need for additional software development to extend the data collection range, function, or purpose of a questionnaire. According to MITRE in its Inspector version 1.0 Description of August 2000, "New questions can be added at-will whenever the user determines that additional detail is needed." However, at present time, the user will have to submit the request for addition to the SA if there is any need.

2. Information Shared Among Surveys

Inspector currently provides the ability to utilize multiple questionnaires relating to almost any aspect of information technology systems. Inspector provides this capability by using a common "front-end" for questionnaire-formatted data that is facilitated through a simple, web-based, survey presentation and data collection module. Information can then be structured between surveys so that it is directly shared within the database. As a result, data being entered into the LISI questionnaire is also automatically entered into the other surveys as appropriate. For example, by "marking" the presence of Transmission Control Protocol (TCP)/Internet Protocol (IP) in the LISI Survey, it is also entered into the DII COE Runtime Compliance Assessment Questionnaire (a COE Level – 1 requirement) and is likewise properly registered as a Layer-4 protocol in the OSI Reference Model. Similarly, information about a particular USMTF message format entered into the LISI survey is also entered into the USMTF Configuration Control Board (CCB) Functional Analysis Survey and the Mission Needs Statement (MNS) Requirements Profiler. (MITRE, August 2000)

3. Expansion of Questionnaires

There is no limit to the level of detail that can be entered into a survey questionnaire. Inspector currently contains approximately 220 questions covering a wide range of topics. These questions now contain over 3,000 possible answers that are currently composed of over 12,000 individual response fields. During the Systems of Systems Interoperability Evaluation meeting in October 2000, Bruce Thompson, LISI Manager from MITRE, indicated that Inspector started with only twenty-five questions in the very beginning. When a hard copy was requested in April 2001 to show attributes with "all questions," a stunning 571-page report was printed.

Although the LISI Interoperability Survey is growing larger on the whole, any one system typically answers only a small subset of these questions. The questionnaire is organized hierarchically so that only those questions that relate to the capabilities being registered for the system need be answered. For example, systems indicating Link-16 on a higher-level question would answer an additional eight questions that would not be shown to other systems that do not indicate Link-16 capability. Likewise, there are 16 questions about USMTF composed of over 400 different message formats which are shown only if "USMTF" is asserted on a higher level question involving what message formats are supported within the system. (MITRE, August 2000)

4. Questions Related to PAID Attributes

Current questions within the LISI *Procedures* attribute address the following subject areas:

- What implementation or enterprise directed standards are being followed?
- What is the system's security profile; which specific security standards are implemented?
- To what degree has DII COE compliance been attained, if applicable?
- What information exchange requirement agreements have been attained within particular domains, within the DOD Enterprise, across-government agencies, and within multi-national forums?

Within the *Applications* attribute, questions are used to evaluate many different application selections including such areas as word processing, briefing development packages, tabular spreadsheets, imagery display tools, map display tools, and what collaboration capabilities exist.

The two LISI attributes that presently contain the greatest amount of detail are *Infrastructure* and *Data*. The questions for *Infrastructure* start by identifying what simple interactions exist between systems and progress through radio, networks, and types of bands, local area networks, wide area networks, and finally multi-level secure configurations. The *Data* attribute covers the spectrum from proprietary data protocols, through advanced heterogeneous data products to full database model implementations. (MITRE, August 2000)

D. LISI PROCESS

1. Generating an Interoperability Profile

The system information collected is consolidated and presented by subject area and is also mapped to the LISI levels. This information is then kept as the basis for constructing interoperability Profiles and performing LISI assessments. The information gathered must contain enough detail to allow selection of options that characterize the system, based on the implementation choices available in the LISI Options Tables. The details are then overlaid on the LISI Capabilities Model to form the system's Interoperability Profile. The LISI Capabilities Model and its supporting LISI Options Tables together constitute the "engine" that drives the LISI process and provide the basis for developing the LISI products (outputs, will be discussed in Section 3.5). For each entry identified in the LISI Capabilities Model, there is typically a variety of means and implementations possible. The LISI process **does not** dictate which implementation must be used; it captures what has been selected or what is being considered.

Figure 3-2 illustrates the process of generating a system's Interoperability Profile. The LISI Capabilities Model is shown on the left. Samples of the associated LISI Options Tables for *infrastructure* implementations are shown in the center of the figure.

Figure 3-2 shows the *infrastructure* portion of the system's interoperability profile. As implied in the figure, for any capability described in the LISI capabilities Model and associated LISI Options Tables, multiple implementations are possible (e.g., Secret Internet Protocol Router Network (SIPRNET), Non-Secure Internet Protocol Network (NIPRNET) and Joint Warfare Intelligence Center Systems (JWICS)). Based on the answers to the LISI questions for the system under analysis, the system's characteristics are captured and mapped against the options tables. In this example, the system represented by S1 has SIPRNET and DISN-LES *infrastructure* capabilities and then these characteristics are captured in the system's interoperability profile. (C4ISR, 1998)

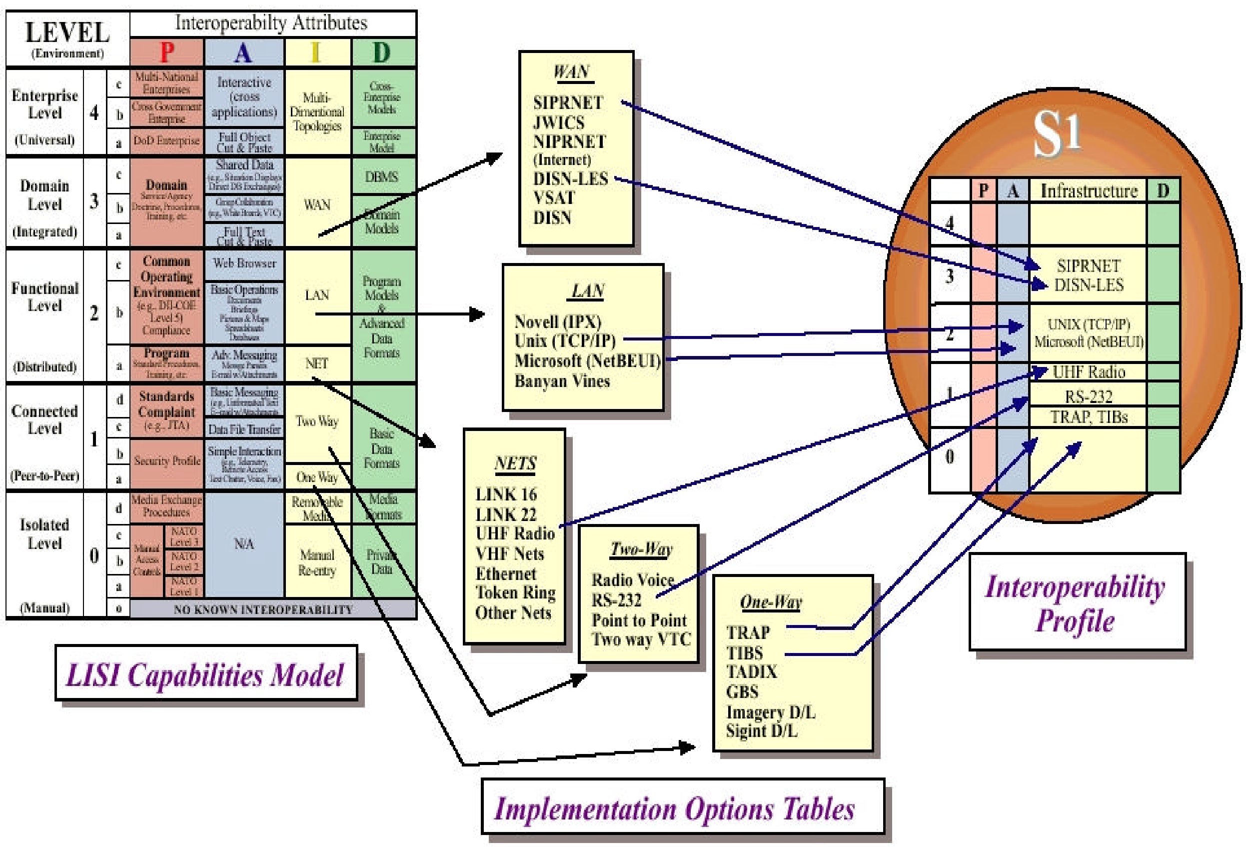

Figure 3-2. Generating an Interoperability Profile, from (C4ISR, 1998)

2. LISI Levels and Threshold Rules

A capabilities model provides a means to identify the distinctions among systems. It is defined in terms of the discriminators that characterize the specific capabilities

within a system. These discriminators determine the specific nature and level of interoperability of a system. In order to be assessed at a certain level, systems must fulfill all of the requirements identified within the PAID attributes up to the level attained. Therefore, the LISI level attained by a system is the "highest line" across PAID up to which all of the requisite PAID capabilities have been implemented and whose implementations have been assessed as interoperable. Furthermore, for each PAID attribute, the level attained within the individual attribute is attained only when all capabilities of the lower thresholds are represented within that attribute.

Decisions about which thresholds within each attribute are essential or can be treated as inherited are embodied within two basic rules:

Threshold Rule 1: Within the capabilities model, there are explicit and essential capabilities that every system must possess. These capabilities act as barriers to being rated at a higher level until they are accomplished. For example, if standards compliance is defined by the enterprise to be an essential characteristic of the *procedures* attribute for Level 1c/d, then a system that is not standards compliant cannot be rated higher than Level 1b. This condition applies, regardless of whether all the other characteristics of the PAID attributes are otherwise fully Level-2b compliant, including those capabilities higher up within the *procedures* attribute.

Threshold Rule 2: Within the capabilities model, thresholds are considered as being "credited" to the next higher level if they have not been designated as an essential and required capability as defined in Rule 1. For example, if a system possesses the LAN characteristic for the *infrastructure* attribute (Level 2b) and the other three PAID attributes also assess at this level, then the system does not specifically require the existence or implementation of each lower-level threshold (e.g., removable media) within the *infrastructure* capability to be assessed as Level 2b. (C4ISR, 1998)

E. LISI OUTPUT

The collection and process of registered profiles provide the basis for conducting system comparisons. The results of these comparisons can be displayed in a number of

products that are available to describe single systems and support comparisons between multiple systems. These products can be based on any of the user-defined x-y coordinate-based reference models included within the tool. LISI Inspector leverages the data captured in the questionnaire to generate the following four primary sets of assessment products. Each set differs in its presentation, its intended use, and the interoperability aspect it considers. (C4ISR, 1998)

1. Interoperability Profiles

The Interoperability Profiles map LISI Questionnaire data (answers) to the LISI Capabilities Model template. Thus, the profiles capture the implementation choices for each PAID capability present in the systems being assessed in a format that facilitates system-to-levels and system-to-system comparisons. Individual system metrics can be generated from these profiles.

a. Generic Interoperability Profile

It maps a **single system's** responses to the questionnaire directly to the LISI Capabilities Model template. The *generic* level of interoperability is the highest level at which the full suite of capabilities is implemented in a given system across PAID.

b. Specific Interoperability Profile

It shows only the common or compatible implementations between the **two systems**, the basis for determining the highest level of sophistication that the two systems can support in their interactions with each other.

c. Composite Interoperability Profile

It shows the commonalties between **a group of systems.**

d. Target Interoperability Profile

It represents **a notional set of system** characteristics for use by developers when designing new systems or updating existing systems. This profile is different than the other three interoperability profiles in that it represents a goal or direction for **types**

or classes of systems. It may initially be constructed from the results obtained using a Composite Interoperability Profile for a set of systems from a particular domain.

e. Variations of Interoperability Profiles

Variations can be applied to any of the above profiles. The profiles described above can be varied in different ways to change the conditions under which the information about a system or group of systems is presented.

2. Interoperability Assessment Matrices

These matrices interrelate groups of systems based on their generic, expected, and specific interoperability metrics, i.e., levels. The results are presented in a "system" format that enables each system pair to be compared in depth. The *generic* level of interoperability is the highest level at which the full suite of capabilities is implemented in a given system across PAID. The *expected* level of interoperability is determined by comparing the generic levels of any two systems. The *specific* level of interoperability is determined by comparing each system's specific implementation choices.

The "scorecard" nature of this product makes it highly useful to all players involved in systems development, acquisition, testing, and oversight, as well as to those responsible for mission and crisis planning and execution. The following are the three types of Interoperability Assessment Matrices: (C4ISR, 1998)

a. Potential Interoperability Matrix

It can be generated for a group of systems based on the generic interoperability level of each system and the specific interoperability level for each system pair within the group.

b. Evaluated Interoperability Matrix

This is a form of the *Potential Interoperability Matrix* that has been validated via testing and experimentation. Therefore, this matrix reflects demonstrated levels of interoperability attained between systems. It is derived via editing the *Potential Interoperability Matrix* to reflect actual field posture.

c. Projected Independence Matrix

It is developed in the same manner as the *Potential Interoperability Matrix*, except that *Projected Interoperability Matrices* are provided for phases in time, each phase corresponding to a planned or postulated suite of capabilities and implementations.

3. Interoperability Comparison Tables

These tables present the results of a system-to-system *PAID* implementation assessment. They provide a comparison of interoperability implementation information between systems in terms of *PAID*.

a. PAID Implementation Comparison Tables

They facilitate attribute-by-attribute examination of the specific *PAID* implementation choices between system pairs, and provide linkages to solution alternatives. These tables would be used to determine the Specific Interoperability Level between systems as well as to examine the nature of the gaps and solution options available. Each table focuses on one of the *PAID* attributes.

b. Interconnection Requirements Table

It represents "data flow" direction between systems. When a PM registers a system using LISI, there is a portion of the questionnaire that calls for the identification of all other systems involved in the system's one-way or two-way information exchanges. When these identified requirements are compared across systems, unknown or unexpected relationships often are exposed. Therefore, the table serves to identify conflicts that would require PM-to-PM coordination to resolve. (C4ISR, 1998)

3.5.4 <u>Interoperability System Interface Description</u> – It reflects the interoperability aspects of information technology architectures. LISI currently supports a system interface diagram that depicts the interoperability level of individual systems and the interfaces between systems that are involved in a particular mission operation or that are under scrutiny.

F. LISI DATA PRIVACY AND CONTROL POLICY

LISI data privacy is highly protected by design for all systems registered in LISI. However, there is an open security issue, as this writing, regarding the classification level the LISI database should properly be set at has not resolved yet.

There are several control points that would demonstrate this high level of protection as depicted in Figure 3-3.

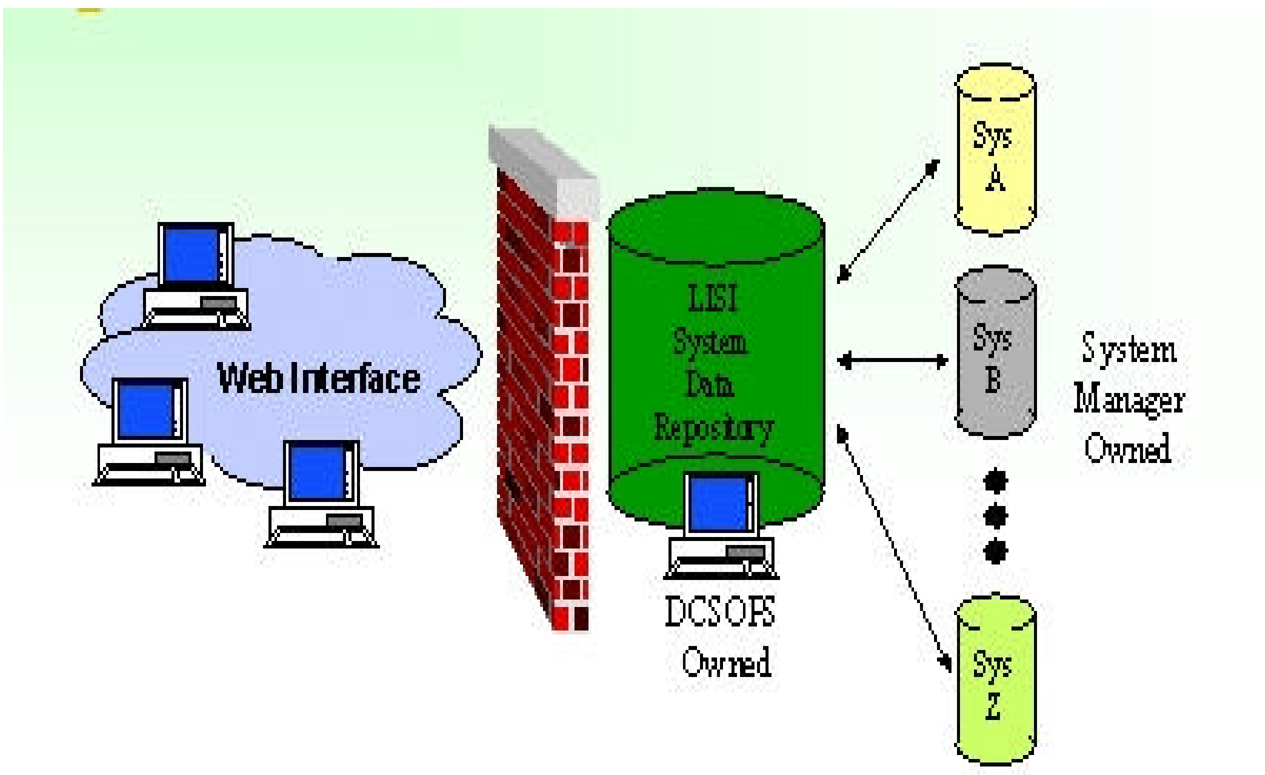

Figure 3-3. LISI Privacy & Control Policy, from (Levine, 2000)

a. The LISI system data is configuration managed by Deputy Chief of Staff for Operations (DCSOPS) who has the ownership rights and report access.

b. The LISI data are input by Program Managers (PM) or System Managers (SM).

c. The LISI data access is web based and certain software and hardware are required for installation and operational use of Inspector as discussed in section 3.2.3.

d. Access to LISI System Data Repository is password protected. Each user requires a user-ID, password, and domain name.

e. A System Administrator for each of the Services controls the passwords.

f. The level of data release for export is controlled by the PM or SM who can decide his input will either remain as "Private," be released to "Local," or be reclassified to "Global" when registering the system based on his data completion level. (Levine, 2000)

G. LISI INSPECTOR USER-FRIENDLINESS

The LISI Inspector, a web-based tool, was designed to provide C4I systems a user-friendly process for determining interoperability needs. The questionnaire information collected in the Inspector is presented in a user-friendly Hyper Text Markup Language (HTML) format, and is captured through an administrative HTML interface.

The LISI Inspector completed a series of major enhancements during FY 99 to make the application of LISI Inspector more user-friendly and meaningful. The improvements during FY 99 have occurred through the contributions of several key organizations. The contributors include the Air Force Electronic Systems Center (ESC) C4ISR Interoperability Program Office (CIPO), the Army Systems Electronic Engineering Office (ASEO), the Horizontal Technology Integration Office (HTIO) at PEO C3S, the Marine Corps Systems Command (MARCORSYSCOM), the Ballistic Missile Defense Office (BMDO), the Unified Cryptologic Architecture Office (UCAO), and the Joint C4ISR Battle Center (JBC). Each contributor also leveraged the expertise of the Program Management Offices (PMOs) and system developers within their purview to support the LISI development. The mentioned system developers are referring to PATRIOT, Airborne Early Warning/Ground Environment Integration Segment (AEGIS), the Theatre Maritime Battle Management Core System (TBMCS), and the Army Battle Command and Control System (ABCS). (MITRE, 1999)

Although the questionnaires currently contain over 220 questions covering 3,000 possible answers with over 12,000 individual response fields, any one system normally

has to answer only a small subset of these questions. The questionnaire is organized hierarchically so that only those questions that relate to the capabilities being registered for the system need to be answered. Also, because the questionnaire data is maintained in a "meta-data" format, new questions can be added "at-will," whenever the user determines that additional detail is needed. (MITRE, August 2000) However, this add-on capability of "at-will" is indirect at the writing of this study, since the user currently can only make a request of any questionnaire change through the system administrator.

The three-levels of data information release is another user-friendly feature. The data input can remain at "Private" level before the system manager or program manager reviews and determines that the data input for the system is accurate and complete. The users can "Print Survey " to see the input before re-classifying the information to the next level, "Local " or "Global." The "Print Survey" also gives the users choices to print the "whole survey" or "one attribute" of the four attributes to narrow down and concentrate on selected review areas.

H. CHAPTER SUMMARY

LISI has been applied through a web-based tool, Inspector 1.0. The Inspector's five major functional components (Survey Questionnaire, Multiple Survey Capability, Reports, Questions Builder, and Data Exchange) make it a powerful tool to capture, manipulate, analyze, and share data for all of its five system surveys currently available (LISI, DIICOE I&RTS v3.1, DIICOE I&RTS v4.0, OSI, and USMTF). Inspector's evolution from a prototype to an operational capability has been driven primarily by expansion of the LISI Survey.

The LISI Survey focuses on the four interoperability attributes: *Procedures, Applications, Infrastructure,* and *Data.* LISI uses the Interoperability Questionnaire to collect the pertinent information required to assess information systems interoperability. Users register system characteristics by selecting the appropriate responses to the questions and then the answers are stored in a table from which data can be used to create a set of reports.

The information collected from the LISI Survey is consolidated and presented by subject area and is mapped into the LISI levels. The details are overlaid on the LISI Capabilities Model to form the system's Interoperability Profile. The LISI Capabilities Model and its supporting LISI Options Tables together constitute the "engine" that drives the LISI process and provide the basis for developing the LISI products. However, the LISI process **does not** dictate which implementation must be used; it captures what has been selected or what is being considered.

LISI Inspector leverages the data captured in the questionnaire to generate four primary sets of assessment products: *Interoperability Profiles*, *Interoperability Assessment Matrices*, *Interoperability Comparison Tables*, and *Interoperability System Interface Description*. Each set of products differs in its presentation, the intended use, and interoperability aspect it considers as discussed under section 3.5, LISI Outputs.

The LISI system data is configuration managed by DCSOPS and its privacy is considered highly protected. A user-ID, password, and domain name is required by each user each time to access the web-based LISI Inspector. Although the questionnaires contain over 220 questions covering 3,000 possible answers with over 12,000 individual response fields, any one system normally has to answer only a small subset of these questions. Also, new questions can be added through system administrator whenever the user determines that additional detail is needed. The data input by the PM or SM may remain as a "Private" file, or be reclassified to either "Local" or "Global" depending on the level of confidence the PM or SM has on the data provided.

The LISI Inspector, a web-based tool, was designed to provide C4I systems a user-friendly process for determining interoperability needs. It has completed a series of major enhancements (contributed by multi-services organizations) during FY99 to make the application of LISI Inspector user-friendlier and more meaningful. Also, in October 2000, Army conducted a Systems of Systems Interoperability Evaluation Meeting to embark on a process that will assist the Army in establishing a framework for sustainment of an interoperability baseline. The continuing effort in enhancing LISI process and implementation to improve C4I system interoperability is anticipated.

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IV. CAN LISI IMPROVE THE C4I SYSTEMS' INTEROPERABILITY?

A. INTRODUCTION

Can LISI improve the C4I systems' interoperability? The answer is "yes" that LISI has the potential to improve DOD C4I systems' interoperability "but" current LISI tool has to be refined. The concept, theory, and mythology discussed in previous chapters, the application and use of the LISI process (will discussed in section 4.2), and the results from two LISI assessments (will be discussed in the sections 4.3 and 4.4) led to the above conclusion.

The motivation and development of LISI was discussed in detail in Chapters I and II. How the LISI process works was also explained in length in Chapter III. LISI was initiated in 1993 and developed to comply with requirements that were eventually codified in the Information Technology Management Reform Act (ITMRA) of 1996 to develop a process and procedure for information technology and to improve system interoperability. Some of the motivations of initiating LISI are to help achieve the "information superiority" envisioned in Joint Vision 2010, to support Joint Task Force, to comply with Information Technology Management Reform Act, and to assist the certifying process and improving C4I systems' interoperability.

The Army pilot assessment conducted by MITRE Corporation and reported in November 1999 indicated that LISI process provides significant added value toward Army system Engineering Office (ASEO) and HTIO's efforts to improve Army Battle Command and Control system (ABCS) interoperability. However, the second assessment conducted by PEO C3S HTIO Interoperability Group and reported in September 2001 pointed out that the current tool has many deficiencies and needs to be refined and upgraded.

B. APPLICATION AND USE OF LISI PROCESS

This section demonstrates the application and use of the LISI process and the potential interoperability improvement capability. It explains how LISI can be used to improve interoperability by assessing, identifying, and recommending corrective actions for major gaps and shortfalls between and among systems throughout different stages of the Army system life cycle. This section also discusses how LISI can be used in different phases of Army system life cycle. The collective work performed across all of these efforts can significantly enhance the interoperability maturity for Army C4I systems.

1. To Develop Interoperability Requirements

LISI can support "requirements" development and analysis for a new program through the development of a *Target Interoperability Profile* (see section 3.5.1.4). Current interoperability profiles of existing systems that support a particular function can be evaluated using the composite *Potential Interoperability Matrix* (see section 3.5.2.1). This matrix shows the interoperability levels between systems already supporting that function. Using this matrix, a *Target Interoperability Profile* for a given system can then be created that will leverage the implementation choices made by other systems that have the same functional needs and relationships. The process of generating a Target Interoperability Profile for a new system is shown in Figure 4-1 below.

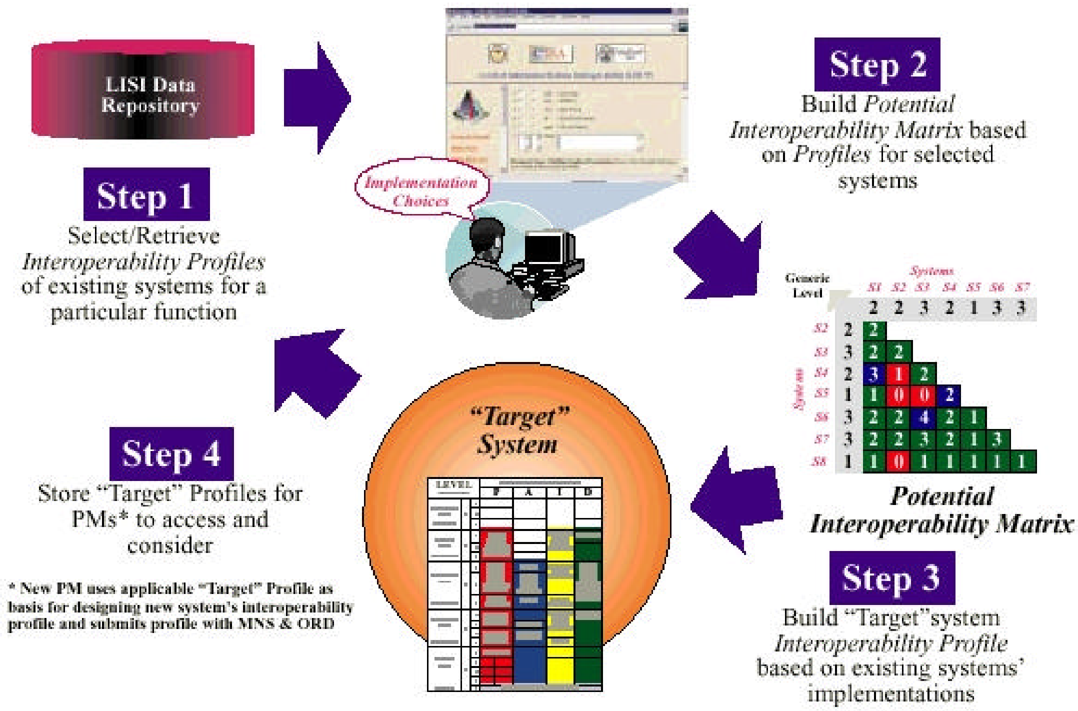

Figure 4-1. Establishing Target Interoperability Profiles, from (C4ISR, 1998)

Step 1: To retrieve profile information for existing systems that performs a particular function.

Step 2: To build the *Potential Interoperability Matrix* for the systems that has been retrieved. This matrix represents the potential for each system to interoperate with the others, and displays the level at which the interactions will potentially take place. This matrix shows the interoperability maturity of the systems supporting the selected function. Gaps and shortfalls are shown and can be targeted for improvement.

Step 3: To combine the profile information for all the systems retrieved into a *Composite Interoperability Profile*. This product will show what all the systems supporting this function have in common. This profile can also be added to the previously generated *Potential Interoperability Matrix* to show how such a "composite" system relates to the existing systems. Additions and changes can be made to this profile based on improving interoperability with existing systems and incorporating future technology directions. Varying the capabilities represented in the Composite Interoperability Profile can

perform risk analysis and cost/benefit tradeoffs. The impact of these changes can be viewed in the Potential Interoperability Matrix and an iterative process used to arrive at the desired "composite" result.

Step 4: To publish the results of the analysis as a *Target Interoperability Profile*. This product provides guidance to PMs and system developers and serves as a benchmark for systems that will support this particular function. Thus, as the capabilities of new systems are developed to support the function, they are built toward a target that already includes interoperability and interfaces to existing systems. On the other hand, where the Potential Interoperability Matrix shows gaps or system-to-system interoperability issues that preclude the clear derivation of "consensus-based" choices, the PMs of the systems in question would be engaged collaboratively to reach an agreed-upon strategy for resolving the implementation differences. Thus, a two-way benefit is realizable. This set of capabilities in the *Target Interoperability Profile* can be included as a supplemental in requirements documents and specifications for the new system. In the DOD, these documents include a Mission Needs Statement (MNS) and an Operational Requirement Document (ORD).

A major benefit of using LISI in this manner is that interoperability requirements and specifications for the given system would be based heavily on the popular or common implementations of the **PAID** capabilities that are inherent in other systems involved in similar Joint information exchanges. This accessible 'view" into the profiles and implementations of other systems underlies a fundamental value of LISI in achieving interoperability "convergence' across DOD over time.

The following are some representative types of questions that LISI helps to answer:

- What other systems may need to interoperate with System X?
- What are the specific interoperability characteristics of these systems?
- Projecting a System-X profile, what does the *Potential Interoperability Matrix* reveal (any gaps or shortfalls)?
- What strategy will the systems agree to for eliminating interoperability gaps? (C4ISR, 1998)

2. To Improve Interoperability of An Existing System

One purpose of the program management process is to identify areas for improvements in existing systems and to transition to more mature states or higher levels of interoperability over time. LISI can identify interoperability shortfalls of an existing system as well as show how changes to that system will improve its interoperability. After entering the information about a system into LISI, a PM can then select and retrieve data about other existing and planned systems for comparison. This cross-systems examination allows PMs to find potential gaps and shortfalls in their own programs as well as the impacts to the other programs

For example, a PM of one system may have made a particular **PAID** implementation choice that impaired the interoperability of that system with two other systems. By using LISI, the PM can identify the potential problem and rectify the condition in the analysis phase of development rather than discovering the issue after fielding.

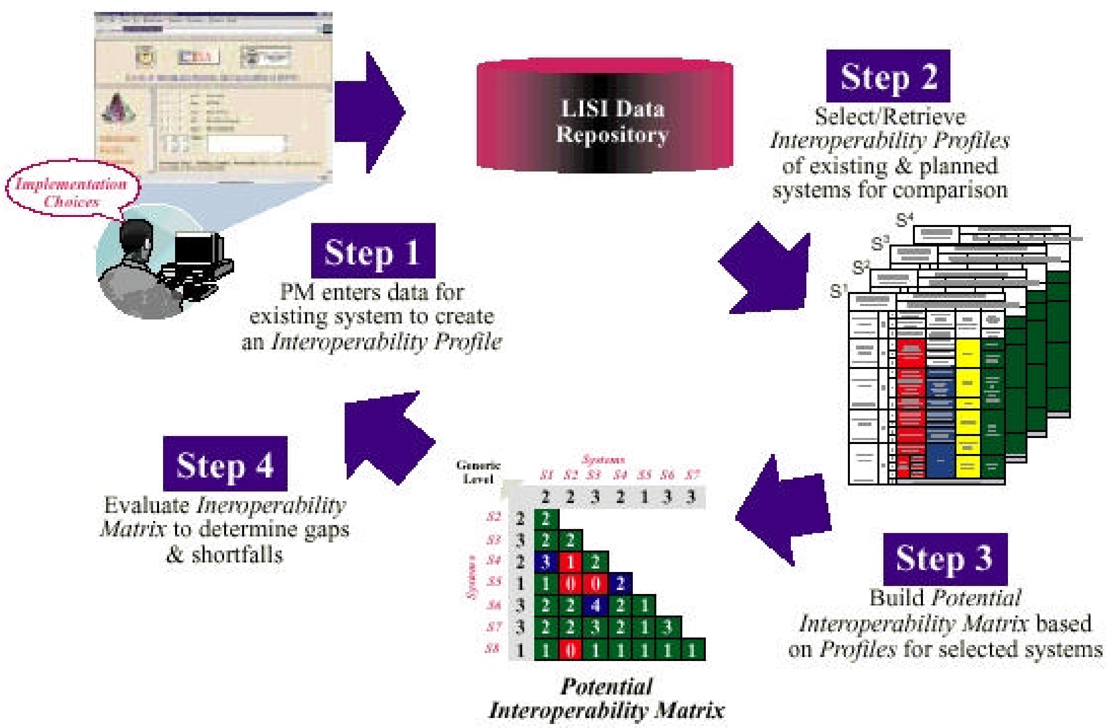

Figure 4-2. LISI Use by PM of an Existing System, from (C4ISR, 1998)

How LISI can be used by the PM of an existing system to improve interoperability is depicted in Figure 4-2 above.

Step 1: To enter data about the system. This data goes into a central LISI repository where other system PMs will have access to it for doing comparisons.

Step 2: To retrieve LISI data about other relevant systems. The PM performs this task by selecting the appropriate systems from the database.

Step 3: To construct a *Potential Interoperability Matrix* based on *profiles* for selected systems.

Step 4: To compare the systems and to detect potential interoperability gaps and shortfalls that appear between the systems.

For each potential problem between two systems, the PM can examine the implementations to determine if the problem can be remedied by changing an implementation selection. The PM can then change LISI data to perform a what-if analysis. The PM can then examine the risk and cost-effectiveness of making the changes required.

Some of the questions that LISI can help to answer are:

- What is the specific LISI potential level of interoperability of System X?
- What specific interoperability issues exist between System X and other systems already in place or planned?
- What is required to raise System X to a higher level of interoperability? (C4ISR, 1998)

3. Use of LISI as an Interoperability Tool for Command Architects

The command architect can retrieve LISI data for systems that comprise an existing or planned architecture. After using LISI to perform an assessment of those systems, the architect can build LISI overlays to architecture products, e.g., the Systems Interface Description (LISI Overlay, see section 3.5.4). The architect can then evaluate alternative strategies to improve interoperability to meet the mission and operational requirements of concern. Figure 4-3 below illustrates the process:

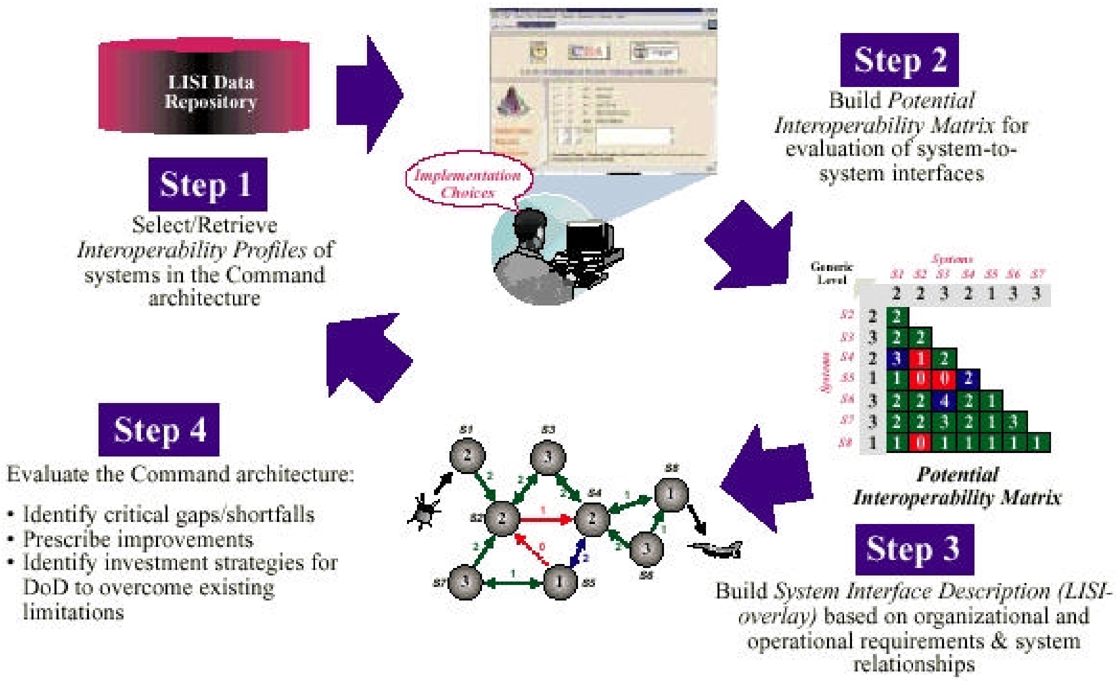

Figure 4-3. LISI Use by a Command Architect, from (C4ISR, 1998)

Step1: The command architect determines which systems are used in the architecture under analysis.

Step 2: The architect retrieves LISI information for those systems from the LISI database and then builds a Potential Interoperability Matrix to evaluate the systems.

Step 3: The command architect builds a System Interface Description (LISI Overlay) corresponding to the operational architecture view under evaluation. Figure 4-3 clearly depicts the interoperability levels of each relevant system and the connecting interfaces in context with the operational requirement, if known. Using notations and colors, this diagram highlights shortfalls where the achievable interoperability is not sufficient to support the mission needs. Where mission needs are not clearly defined, the diagram depicts discrepancies between the systems' assessed generic, expected, and specific levels of interoperability (see section 3.5.2 for definitions).

Step 4: The command architect can use LISI to identify interoperability shortfalls graphically. The command architect can evaluate alternatives by modifying the information on the systems involved and re-running the analysis.

Given a new system to integrate into an existing architecture, LISI can help the command architect answer the following types of questions:

- What is the assessed LISI level for the new system?
- Which systems within the existing architecture is this system potentially capable of interoperating immediately?
- If known, with which system(s) does this system need to interoperate? (C4ISR, 1998)

4. Use of LISI for Interoperability "On the Fly"

LISI can be used to assess interoperability of existing systems, as they are being planned and combined for operational use. For example, the DOD Joint Task Forces (JTF) does not exist until the need arises. When a crisis appears imminent, a variety of systems are brought together by the Services and Agencies who will be participating in the mission. These systems may or may not interoperate; the new crisis could dictate system-to-system relationships that have not been conceived of before. When the JTF has a short lead time, the problems associated with getting disparate systems to interoperate may force the Commander of the JTF to get by without critical information that otherwise would be accessible and transferable if the supporting systems interoperate at the requisite levels. LISI can be used at any point the JTF crisis "life cycle" to help identify and mitigate interoperability problems. This application may be repeated throughout the life cycle of the JTF many times as systems and nodes come and go within the architecture. Figure 4-4 below depicts the process:

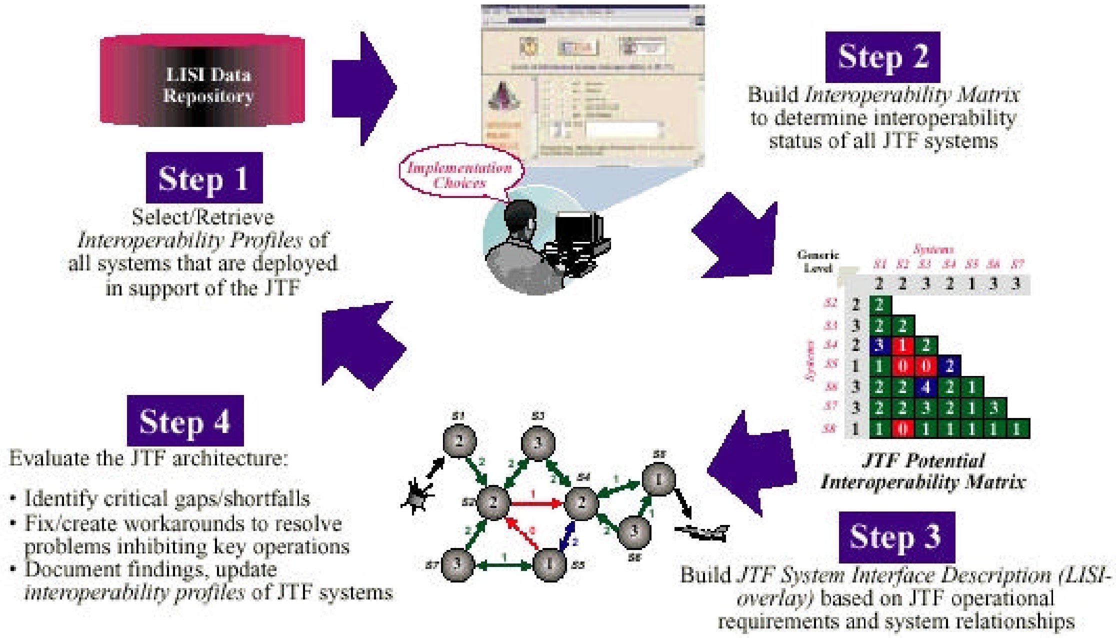

Figure 4-4. LISI Use to Assess Interoperability "On the Fly", from (C4ISR, 1998)

Step 1: JTF planner determines which systems will support the JTF. Then, the JTF planner retrieves LISI data for those systems from the LISI data repository.

Step 2: The planner builds the Potential Interoperability Matrix for all of the systems to evaluate the potential of each of the systems to interoperate.

Step 3: The JTF planner builds a JTF *System Interface Description (LISI Overlay)* based on JTF operational requirements and system relationships. The foundation of the diagram shows the mission's node-to-node information need lines and required interoperability levels. The diagram then "overlays" the supporting systems and assesses where the LISI level of interoperability is not sufficient to satisfy the need line requirements.

Step 4: The JTF planner can evaluate alternatives by modifying the interoperability profiles of the systems involved and re-running the analysis. When an acceptable alternative is reached, the systems can be modified, if practical, to change their interface characteristics as required such as adding an Ethernet card to a machine to allow it access to an Ethernet LAN. Rapid analysis and improvements can be facilitated by LISI's

process and augmented by an appropriate test environment, such as Joint Battle Center and federated laboratories.

Given the need to make disparate systems interoperate in a short time, LISI can help a JTF planner determine the following:

- Does the right kind of interconnection exist between systems?
- What are the “critical” pathways?
- What capabilities need to be deployed to augment the infrastructure that is in place?
- Can the necessary data get to the right person in the time required?
- What vulnerabilities exist with respect to interoperability?
- What additional applications are needed to support the required collaborative exchanges? (C4ISR, 1998)

5. To Support Assessment and Certification

LISI can also be used to support the assessment and certification of systems and applications. One way this can be accomplished is by using LISI data submitted with requirements documents, such as Mission Needs Statement (MNS) and Operational Requirement Document (ORD) for a new program in the preparation of the Test and Evaluation Master Plan (TEMP). The approved TEMP would include LISI assessment criteria that evaluate a system’s interoperability level. The results of these interoperability evaluations can be documented in the test reports. For example, the test report could show that System X is certified at an overall interoperability level of 2a and could also report the individual **P**, **A**, **I**, and **D** levels (i.e., *Procedures* = 2a, *Applications* = 2b, *Infrastructure* = 2c, and *Data* = 2c). Figure 4-5 depicts this process.

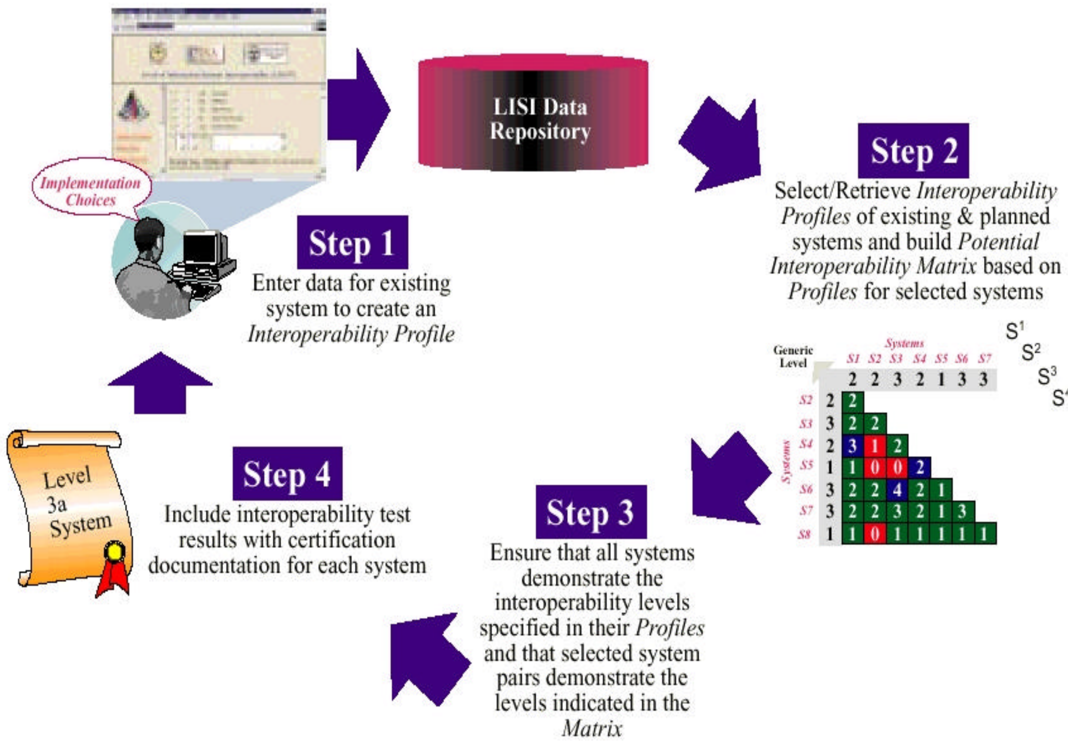

Figure 4-5. LISI Use to Support Systems Assessment and Certification, from (C4ISR, 1998)

Step 1: LISI data for the system to be certified is retrieved from the LISI database.

Step 2: A *Potential Interoperability Matrix* is built based on the interoperability profiles of the existing and planned systems.

Step 3: Testing is conducted to ensure that all systems demonstrate the interoperability levels specified in their profiles.

Step 4: The results are then included with the systems' certification documentation. (C4ISR, 1998)

The use of LISI to support systems/application assessment and certifications is most noteworthy. Generally, newly developed DOD systems are to be denied production approval if they have not been certified. After a system has been fielded and a modification is made that affects interoperability, the system must be re-certified. A GAO report of March 1998, "Weaknesses in DOD's Process for Certifying C4I Systems'

Interoperability," identified several weaknesses in the certifying process (see section 2.3.4 for more information). LISI was one of the initiatives mentioned in the report that would improve ways of complying with the certification process and would lead to resolution of many of the issues related to interoperability.

C. YES, LISI HAS POTENTIAL TO IMPROVE ARMY SYSTEM INTEROPERABILITY

In support of the ASEO and in coordination with the HTIO, MITRE Corporation conducted the Army pilot assessment and reported in November 1999 that LISI can improve ABCS interoperability. This assessment was conducted by applying the LISI prototype to various interoperability aspects of the Army Battle Command System (ABCS) only. The report indicated, "The findings of this assessment clearly indicate how the LISI process provides significant added value towards ASEO/HTIO's efforts to improve ABCS interoperability. The collected ABCS systems data sufficiently demonstrated the LISI methodology and Prototype capabilities that are now available for exploitation by ASEO/HTIO." (MITRE, November 1999)

1. Background of the LISI Pilot Assessment

In November 1999, Army System Engineering Office (ASEO), PEO C3S Horizontal Technology Integration Office (HTIO), and MITRE Corporation completed a joint effort in assessing LISI using components of the Army Battle Command System (ABCS). The assessment effort was conducted between 1 March and 30 September 1999 and the final report was completed in November 1999.

The report discusses the development and use of the LISI prototype tool in its application to Army Systems, mainly, the eleven highly complex ABCS systems. The eleven systems include Advanced Field Artillery Tactical Data System (AFATDS), Air and Missile Defense Planning and Control System (AMDPCS), All Source Analysis System (ASAS), Combat Service Support Control System (CSSCS), Digital Topographic Support System (DTSS), Force XXI Battle Command _ Brigade and Below (FBCB2),

Global Command and Control System – Army (GCCS-A), Integrated Meteorological System (IMETS), Integrated System Control (ISYSCON), Maneuver Control System (MCS), and Tactical Airspace Integration System (TAIS).

The report of the pilot assessment recognized that its data might not be complete, detailed or fully validated: "Since the current ABCS data in LISI has not yet been validated, the LISI analysis conducted during this assessment was limited to providing initial observation, **not definite conclusions**, regarding ABCS interoperability." (MITRE, 1999) Although the interoperability profiles and matrices produced from the assessment might not reflect the true interoperability postures among the eleven systems at the time during the pilot assessment, the information available on these systems was sufficient to demonstrate the LISI methodology and prototype capabilities that are now available. (MITRE, 1999)

2. Data Analysis from the Pilot Assessment

The LISI Prototype's analytical capability was exercised with the set of collected data. LISI Prototype reports were examined with respect to (1) their inherent value in assessing information systems interoperability, and (2) specific observations for ABCS component interoperability. Using System I as an example, the following paragraphs demonstrate how the System I data is analyzed, mapped to matrix and profile, and used for identifying shortfalls and recommending remedies.

a. Generic Interoperability Profile

It maps System I's (a single system's) responses to the questionnaire directly to the LISI Capabilities Model. This mapping forms the basis for determining a system's generic interoperability level. The generic interoperability level is the highest level of sophistication at which a system could generally be expected to interact with any other system in an environment or community. The generic level is calculated by examining the system profile from the bottom up and determining the highest level at which implementations are present across the four attributes, P, A, I, and D. Figure 4-6 shows how the generic interoperability profile for System I is summarized as "1c."

Generic Interoperability Profile

System I ABCS 6.0

The metric for System I is: **1c (P1c A4a I3c D2c)**

LISI		*Procedures*	*Applications*	*Infrastructure*	*Data*
Enterprise Level 4	**c**	**Multi-National Agreements (IERs)**	**Interactive-Cross Organization Applications**	**Multi-Dimensional Topologies**	**Multi-National Based Data Models**
	b	**Cross-Government (IERs)**	**V V**	**V V**	**Cross-Government Data Models**
	a	**Cross DoD C/S/A Agreements (IERs)**	**Full Object Cut & Paste**	**V V**	**Enterprise Based Data Models**
Domain Level 3	**c**	**Domain Agreements (IERs) Service/Agency Doctrine, Procedures, Training, etc.**	**Shared Data (e.g., Situation Displays, Direct DB Exchanges)**	**Wide Area Network (WAN)**	**DBMS Implemented**
	b	**V V**	**Group Collaboration Capabilities**	**V V**	**Domain Based Data Models**
	a	**V V**	**Full Text Cut & Paste Between Applications**	**V V**	**V V**
Functional Level 2	**c**	**Common Operating Environment (DII COE Level 6+)**	**Web Based Access Enabled**	**Local Area Network (LAN)**	**Individual Program Models**
	b	**(DII COE Level 5)**	**Basic Operations (Create/Display: Documents, Briefings, Images, Maps)**	**V V V**	**Advanced Data Formats**
	a	**Program (DII COE Level 4-)**	**Advanced Messaging (Automated Msg Parsers, Email w/attachments)**	**NET (e.g., Radio Net)**	**V V V**
Connected Level 1	**d**	**Enterprise Standards Compliance (e.g., JTA, DODIIS)**	**Basic Messageing (Unformatted Text, Email w/o attachments)**	**Two-Way Communications**	**Basic Data Formats**

	c	**V** **V**	**Data File Transfer**	**V** **V**	**V** **V**
	b	**Security Profile (Accreditation, Standards)**	**Simple Interactions (Telemetry, Remote Access, Text)**	**V** **V**	**V** **V**
	a	**V** **V**	**V** **V**	**One-Way Comms (Broadcast)**	**V** **V**
Isolated Level 0	**d**	**Media Exchange Procedures**	**No Requirement**	**Removable Media Types**	**Removable Media Formats**
	c	**Manual Access Controls (NATO Level 3)**	**V** **V**	**Manual Re-Entry**	**Private Data Formats**
	b	**Manual Access Controls (NATO Level 2)**	**V** **V**	**V** **V**	**V** **V**
	a	**Manual Access Controls (NATO Level 1)**	**V** **V**	**V** **V**	**V** **V**
	o	**No Known Interoperability**	**No Known Interoperability**	**No Known Interoperability**	**No Known Interoperability**

Figure 4-6. Example Generic Profile for System I, from (MITRE, 1999)

b. Generic Interoperability Levels (Reported Level)

They are summarized in Figure 4-7 below. Waiving JTA compliance would produce the indicated "Waived' level. The System I generic interoperability level of "1c" was derived from the generic interoperability profile as shown in Figure 4-6 above.

ABCS 6.0 Systems	Reported Level	“Waived” Level
System A	1c	2c
System B	1c	1d
System C	0o	0o
System D	1c	2c
System E	1c	2c
System F	1c	1d
System G	0o	2c
System H	0o	0o
System I	**1c**	2c
System J	0o	0o
System K	1c	2c

Figure 4-7. Generic LISI Levels Based on Reported Capabilities, from (MITRE, 1999)

c. Interoperability Assessment Matrix

It was derived from some of eight complete sets of ABCS system surveys and as shown in Figure 4-8 below. The boxes are colored and indicated in the legend. To prevent the indifference of the colors when it is printed in black and white, the boxes are also indicate the color by a capital letter corresponding to its appropriate legend, that is, B for Black, G for Green, L for Blue, R for Red, and Y for Yellow as shown below.

Systems		A	B	D	E	F	G	I	K
Generic Level		**1c**	**1c**	**1c**	**1c**	**1c**	**2c**	**1c**	**1c**
A	**1c**	***2c*** **L**							
B	**1c**	***1b*** **Y**	***3c*** **L**						
D	**1c**	***1a*** **Y**	***1c*** **G**	***2c*** **L**					
E	**1c**	***1a*** **Y**	***1c*** **G**	***1a*** **Y**	***2c*** **L**				
F	**1c**	***1c*** **G**	***1a*** **Y**	***1a*** **Y**	***1a*** **Y**	***1c*** **G**			
G	**2c**	***0o*** **R**	***1b*** **Y**	***1b*** **Y**	***1b*** **Y**	***0o*** **R**	***2c*** **G**		
I	**1c**	***0d*** **R**	***1c*** **G**	***0d*** **R**	***1c*** **G**	***0o*** **R**	***1b*** **Y**	***2c*** **L**	
K	**1c**	***1a*** **Y**	***1c*** **G**	***1a*** **Y**	***2a*** **L**	***1a*** **Y**	***1b*** **Y**	***1c*** **G**	***2a*** **L**

B	**No Interoperability Identified**	Y	**Specific LESS but SAME LEVEL as Expected**	L	**Specific GREATER then EXPECTED**
R	**Specific LESS than Expected**	G	**Specific EQUALS Expected**		

Figure 4-8. ABCS 8-System Interoperability Assessment Matrix, from (MITRE, 1999)

This matrix indicates major gaps or significant shortfalls (red conditions) for 5 system pairs. System I-to-System F and System G-to-System F do not currently reflect a requirement to interact. The remaining 3 pairs (System A-to-System G; System I-to-System A; and System I-to-System D) have interaction limitations identified in their respective individual interoperability profiles.

d. Specific Interoperability Profiles

It is used to examine a particular interoperability assessment matrix cell in greater detail to find gaps and shortfalls, and to indicate solutions. Attributes (*Procedures*, *Applications*, *Infrastructure*, and *Data*) are each detailed to identify specific

common and different capabilities. *Specific Interoperability Profiles* were generated for one of the ABCS system pairs: one of the "red" conditions (System I-to-System D). They are assessed as examples of how the LISI profile may help identify and resolve problems. Figure 4-9 identifies the interoperability levels of each attribute for the following system pairs.

System Pair	**Combined PAID**	**Procedures**	**Applications**	**Infrastructure**	**Data**
System I-to-System D	0d	1c	3a	0d	2b

Figure 4-9. LISI Interoperability Levels for the System Pairs, from (MITRE, 1999)

3. Findings from the Pilot Assessment

In its final report of the pilot assessment, MITRE Corporation concluded that application of the LISI Prototype demonstrates LISI's potential utility in making useful insights in improving interoperability of Army systems. For ASEO and HTIO, LISI presented profiles of the current ABCS components at a level of detail sufficient to:

- Discern the level of sophistication at which the ABCS components could potentially interact.
- Define the nature of that interaction.
- Characterize the capability improvements in each program, such as adding mapping or office automation to the applications, adding infrastructure capabilities, or adopting of domain data models.
- Provide a perspective for requirement-based interoperability assessments, such as providing AFATDS Interface Control Document (ICD) view versus AFATDS PMO view.

The findings of this assessment clearly indicate that the LISI process provides significant added value towards ASEO and HTIO's efforts to improve ABCS interoperability (MITRE, 1999).

D. BUT, THE CURRENT LISI TOOL HAS TO BE REFINED AND UPGRADED

PEO C3S HTIO was tasked by Directorate of Integration (DOI) to provide suggestions for improvements to the LISI questionnaire and associated reports. In September 2001, HTIO submitted a LISI Final Report and Analysis to DOI. The primary source of the data for this evaluation covers DOI-selected ABCS systems. (Paterson, 2000) The PEO C3S HTIO also manages this data collection. In the report, HTIO indicated that there are deficiencies in the LISI tool, particularly in the on-line questionnaire, and refinement and upgrade of LISI tool is needed. The following discussions include some examples of the findings and recommendations from HTIO assessment.

1. Expand the Question and Answer Choices

- Under (Attributes/Procedures) the question entitled Operating Environment Types, there are more environments than the choices would indicate, need to have an add-in box to accommodate.
- Under question Document Exchange Formats, we need an expanded dropdown list box.
- Under question Operation Networks, answer choices provided are not adequate or comprehensive enough. For example, there is no Tactical Internet Upper or Tactical Internet Lower operational network as the Army uses. Additionally, these questions must have fill-in boxes because explanations are critical to explain particular system hardware set-ups within their infrastructure. (Stubins, 2001)

2. Clear Ambiguous and Misleading Questions

- There is quite a bit of confusion concerning the exact definition of the differences between the JVMF messages and the (old) VMF messages. Exactly what it meant by when asking if a user uses (old) VMF messages.

- Under Removable Media, what are we looking for, the device itself? Or the media in the device?
- Under question Security Measures, this question needs to be tightened up considerably. There are numerous categories security measures fall under. This is another case of the question meaning anything the user wants it to mean.
- Throughout the questionnaire users are asked whether or not items are available and if they are required. The question of what is and isn't required falls outside the goals of the LISI questionnaire. Questioning the users requirements only serves to feed the users insecurities about hidden agendas. (Stubins, 2001)

3. Require knowledgeable Person to Input LISI Data

Garbage in and garbage out, the LISI output for the interoperability assessment and improvement are only as good as the data. LISI tool uses the Interoperability Questionnaire to collect the pertinent information through the web-based Inspector version 1.0. The questionnaire is linked to the LISI models and tables that comprise the assessment basis.

Inspector currently contains approximately 220 questions composed of over 12,000 individual response choices. Each field checked for every question eventually will lead to a profile decision-making. The person inputting the data needs to be thoroughly knowledgeable about the C4I system itself, to know how to use the LISI tool, and to properly fill out each of the questionnaire for useful analysis.

4. Concentrate on Fewer Reports with the Highest Quality

In the second assessment report, HTIO indicated LISI test outcomes depend on algorithms that are unknowns to the world outside the coder. It is difficult if not impossible to intelligently comment on "black boxed" report outcomes without possessing knowledge of the processes that are driving the report outcomes. HTIO also recommended that the entire LISI report structure requiring replacement with a modern, customer-centric design. A requirements description detailing the necessary reports needs to be written. (Stubins, 2001)

E. PROVIDE FUNDING AND RESOURCES TO UPGRADE LISI

HTIO, PEO C3S has been the Army lead in LISI efforts. After the pilot assessment, HTIO recognized the need for LISI continuing improvement and submitted a Rough Order of Magnitude (ROM) estimate on 21 October 1999 to request for funding in the amount of over $800,000. (PEO C3S, 1999) The estimate was to fund manpower and training for Database Logical Design and Physical Schema, System/Server Architecture and Interface Design, Application Design and Development, Database Initialization, and Training. In addition, the funds are needed to purchase three servers with workstations for System Development Environment, Web application development tools, SQL Server Development Environment, MS Developers Kit, VB Development Environment, ERWin, and NetVis or VISIO for output graphics, etc. However, the funding was never approved.

To correct the deficiencies as discussed above will cost money, therefore, funding and resources should be property allocated. Also, "Interoperability is an ideal condition that can be approached but never totally achieved because of the dynamic nature of military operations, system acquisition, and technology improvements." (JITC, 2001) Therefore, the continuing of LISI evolution and maintenance is unavoidable and the funding to continue the enhancement and maintenance of LISI is essentially required.

F. CHAPTER SUMMARY

After the data about the existing and developing systems have been registered using the *LISI Interoperability Questionnaire* and are stored in a repository or database for easy access, LISI can provide a quantitative interoperability assessment for Program Managers (PMs) and system developers to assess their program interoperability during the entire system life cycles. LISI can be used in developing interoperability requirement for a new system. It can improve interoperability of an existing system/application. It can be used as an interoperability tool for command architects. It can be used for

interoperability "on the fly."   Also, it can be used to support interoperability assessment and certification.

MITRE Corporation concluded in its 1999 assessment for HTIO that application of the LISI Prototype demonstrated LISI's potential utility in making useful insights into C4I Systems for improving interoperability of Army systems. It also clearly indicated that the LISI process provides significant added value towards ASEO and HTIO's efforts to improve ABCS interoperability (MITRE, 1999).

However, in the 2001 assessment, HTIO indicated that the current LISI tool needed to be refined. The choices of questions and answers need to be expanded. Ambiguous questions have to be cleared or avoided. LISI data has to be input by persons knowledgeable in both the C4I systems and LISI tool.   Reports produced should only be high quality and meaningful.   To correct the above deficiencies will cost money and should be funded. Also, the resources should be provided to upgrade, to operate, to maintain, and to continue the evolution and enhancement of the LISI system.

To answer the prime thesis question, as whether LISI can improve the C4I systems' interoperability, the answer is that LISI has potential to improve DOD C4I systems' interoperability, but the current LISI tool has to be refined and upgraded.

V. CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

The military services have a long history of interoperability problems during joint operations. The success of the Persian Gulf War in 1991 was hampered by a lack of basic interoperability. Since then, the DOD has had a number of initiatives to address various aspects of interoperability, such as Joint Tactical Architecture (JTA), Defense Information Infrastructure (DII)/Common Operating Environment (COE), DII Master Plan, Shared Data Environment (SHADE), Joint Battle Center (JBC), and Joint Interoperability Test Command (JITC). Among these initiatives, LISI is the key tying all the initiatives together.

Commencing in 1993, MITRE Corporation has been the developer for LISI process and its associated software applications and LISI has continued to advance in capability through several evolutions: The Exploratory Phase in 1994, Analysis Phase in 1996, Proof of Concept Phase in 1997, Development Phase and pilot assessment in 1999, culminated in the mandatory use of LISI in 2000. The 1999 Development Phase was accelerated as the result of the GAO report entitled: Joint Military Operations: Weaknesses in DOD's Process for Certifying C4I Systems' Interoperability." A pilot assessment of LISI using components of ABCS was conducted by MITRE Corporation in 1999. The mandate of LISI use was directed on 15 August 2000. And the final report of the second assessment by HTIO was submitted on 28 September 2001.

My personal interest in the area of information system interoperability started in August 1997 when I worked in the HTIO, PEO C3S, which manages fifty-plus mission critical C3S systems and has been designated as the Army lead in the LISI efforts. I continue to have the firsthand information on LISI progress even after moving to PM TRCS, one of PEO C3S PM offices, in October 2000. My associate thesis advisor, Mr. Tony Kunsaitis, is the Interoperability Manager for PEO C3S. Mr. Kunsaitis has introduced me to the wonder world of the information system interoperability and the progress of LISI development.

Although LISI was initiated in 1993, it is still foreign to the majority of the program management community even today. I had originally planned for my thesis to show how the LISI can help PMs and hoped to convince them to use LISI. When the use of LISI became mandatory in August 2000, I changed my thesis concentration on whether LISI can improve C4I systems interoperability.

In order to examine how LISI can improve DOD C4I systems' interoperability, detailed explanation of the LISI system itself was discussed in both Chapters II and III. Chapter II provided the overview of LISI, its definition, elements, and associated process. It also introduced the motivations for LISI initiation and implementation. Chapter III illustrated how LISI is applied, its security, and its user friendliness. Much of the background information was referenced from the C4ISR Architectures Working Group's LISI report of 30 March 1998.

Chapter IV answered the prime research question as to whether LISI can improve C4I interoperability. The concept, theory, mythology, the application and use of the LISI process, and the results from the two LISI assessments led to the conclusion of this thesis. The conclusions made in this thesis that LISI can improve the information system interoperability are based on the research available as of this writing and is summarized in the following section.

B. CONCLUSIONS TO RESEARCH QUESTIONS

1. What Is LISI?

LISI is a formal Reference Model, an assessment implementation of the interoperability maturity model, and a structured process for improving interoperability between varied information system. The LISI tool provides an automated, web-based interoperability assessment capability. The heart of the LISI concept is the formulation of a system "profile," which was created by LISI web-based tool, Inspector 1.0. The "profile" may become the common denominator for determining interoperability between C4 systems but it certainly not a prescription for guaranteeing interoperability.

Therefore, LISI is a tool and process to assess and measure but not to guarantee the interoperability of information systems.

2. What Are Central Elements of LISI And Associate Process?

The LISI process focused on defining and assessing systems against increasing levels of sophistication for system-to-system interaction. The process defines thresholds of capabilities that a system exhibits as it improves and matures in its ability to interact with other systems. These thresholds become levels of interoperability that can be measured consistently throughout the system's life cycle. LISI also categorized the various aspects of information systems interoperability in terms of four comprehensive and closely interrelated attributes. Therefore, the "Levels" and the "Attributes" are the essential elements of LISI. LISI considers five increasing levels of sophistication with respect to exchanging and sharing information and services. Each higher level represents a demonstrable increase in capabilities over the previous level of system-to-system interaction. This increase is expressed in terms of the *PAID* attributes – the **Procedures** imposed by information management, the capabilities of **Applications** that act on that data, the type of **Infrastructure** required, and the nature of **Data** transferred.

3. What Are the Motivations to Implement LISI?

- **To Achieve Information Superiority**: LISI was initiated in 1993 after the difficulties of basic interoperability experienced during the Persian Gulf War in 1991. The Information Superiority envisioned by the Chairman of the Joint Chiefs of Staff in his Joint Vision 2010 in 1997 further challenged the development and implementation of LISI.
- **To Support Joint Task Force**: Although the DOD Joint Task Forces does not exist until the need arises, it is crucial to have existed quick access and ready information whenever the need arises to bring together the supporting systems, which need to be interoperate at the requisite levels. LISI can be used at any point the JTF crisis "life cycle" to help identify and mitigate interoperability

problems. This application may be repeated throughout the life cycle of the JTF many times as systems and nodes come and go within the architecture.

- **To Comply with Information Technology Management Reform Act**: The ITMRA of 1996 requires the Federal Government to develop "a process and procedure for establishing goals for improving the efficiency and effectiveness of government agencies" operations and the ability to deliver goods and services to the public using information technology. The goals must be measurable." Prior to LISI, there were no widely accepted performance-based and results-based standards for interoperability. Now LISI directly supports the development of IT architectures within the context of ITMRA by assessing the level of interoperability required and attained between systems.
- **To Assist in Certifying Process and Improving C4I Systems" Interoperability**: GAO identified several weaknesses in DOD's process for certifying C4I systems" interoperability in its March 1998 report and recommended that a number of interoperability improvement initiatives had to be continued. LISI was one of the initiatives recommended in the report. GAO also indicated "DOD's 1993 LISI initiative is to improve C4 and intelligence systems' interoperability. System developers are to use this tool to assess interoperability, to determine capabilities needed to support system development, and to determine the degree of interoperability needed between C4I and other systems."
- **To Become a Mandatory Interoperability Evaluation Tool**: The Director of Information System for C4 and the Military Deputy to the Assistant Secretary of the Army (AL&T) mandated on their joint memorandum of 19 August 2000 that the HQDA to employ LISI framework and its associated interoperability assessment tool to address SoS interoperability. The rationale was that the technical data stored in LISI along with LISI output products satisfy the C4ISP requirements for a technical architecture profile and view.

4. How Does LISI Process Work?

LISI uses the LISI Survey through a web-based tool, Inspector1.0 to collect the pertinent information required to assess information systems interoperability. User register system characteristics by selecting the appropriate responses to the questions and then the answers are stored in a table from which data are used to create a set of reports.

The information collected from the LISI Survey is consolidated and presented by subject area and is mapped into five LISI levels (zero through four) and in terms of four LISI attributes (P, A, I, and D). The detailed information is overlaid on the LISI Capabilities Model to form the system's Interoperability Profile. The LISI Capabilities Model and its supporting LISI Options Tables together constitute the "engine' that drives the LISI process and provide the basis for developing the LISI products.

LISI Inspector leverages the data captured in the questionnaire to generate four primary sets of assessment products: *Interoperability Profiles, Interoperability Assessment Matrices, Interoperability Comparison Tables, and Interoperability System Interface Description*. Each set of products differs in its presentation, the intended use, and interoperability aspect it considers.

5. Is the LISI System Secure?

LISI data privacy is considered highly protected for all systems registered in LISI. There are several control points that would demonstrate this high level of protection:

- Deputy Chief of Staff for Operations who manage the system configuration and has the ownership rights and report access.
- Program Managers, Systems Managers or their delegates input the data.
- The LISI data access is web based and certain software and hardware are required.
- Access to LISI System Data Repository is password protected. Each user requires a user-ID, password, and domain name.
- A System Administrator for each of the Services controls the passwords.
- Each Program Manager or Systems Manager can decide the level of information release by registering the system as "Private," "Local," or "Global."

6. Is the LISI System User Friendly?

The LISI Inspector, a web-based tool, was designed to provide a C4I-wide user-friendly process for determining interoperability needs. The questionnaire information collected in the Inspector is presented in a user-friendly Hyper Text Markup Language (HTML) format, and is captured through an administrative HTML interface.

The LISI Inspector completed a series of major enhancements during FY 99 to make the application of LISI Inspector more user-friendly and meaningful. Although the questionnaires currently contain over 220 questions covering 3,000 possible answers with over 12,000 individual response fields, any one system normally has to answer only a small subset of these questions. The questionnaire is organized hierarchically so that only those questions that relate to the capabilities being registered for the system need to be answered.

The three-levels of data information release is another user-friendly feature. The data input can remain at "Private" level before the system manager or program manager reviews and determines that the data input for the system is accurate and complete. Also, the users can "Print Survey" to review the input before re-classifying the information to the next level or choose to print the "whole survey' or "one attribute" at a time.

7. Can LISI Improve DOD C4I Systems' Interoperability?

The answer is a "yes, but …" Yes, LISI has potential to improve Army systems interoperability but current LISI tool need to be refined and upgraded.

LISI was initiated in 1993 and designed and evolved to comply with the Information Technology Management Reform Act of 1996 to develop a process and procedure for information technology and to improve system interoperability. A prototype assessment of the LISI using components of the ABCS was used to demonstrate how LISI could be used to improve interoperability. MITRE in its final report of the pilot assessment clearly indicated that the LISI process provides significant added value towards ASEO and HTIO's efforts to improve ABCS interoperability.

HTIO reported in September 2001 from the second assessment that the LISI tool has many deficiencies and need to be refined and upgraded. The choices of questions and

answers need to be expanded. Ambiguous questions have to be cleared or avoided. LISI data has to be input by persons who are knowledgeable in both the C4I system and the LISI tool. Reports produced should only be high quality and meaningful. Also, the resources should be provided to upgrade, to maintain, and to continue the evolution and enhancement of the LISI system.

C. RECOMMENDATIONS FOR FURTHER STUDY

The further study may include but not limited to the following areas:

- <u>LISI Management Support</u>: The mandate of LISI in August 2000 appeared not to have gotten the attention of all levels of management. As of today, LISI is still foreign to most of the program management community. Further study may explore the reasons for this drawback and provide recommendation for improvement.
- <u>LISI Funding Resources</u>: As discussed in section 4.4.5, the continuing of LISI evolution and maintenance is unavoidable and the funding to continue the LISI enhancement and refinement is essentially required. Further study may discuss where the continuing funding should be resourced.
- <u>LISI Tool Advertising</u>: LISI is using the Inspector 1.0, a web-based tool, to capture, manipulate, analyze, and report interoperability assessment. The tool is effective, rather secure, and user-friendly although it requires further refinement and upgrade. However, the tool is still foreign to the majority of the program management community as of today regardless the fact that LISI was initiated in 1993. In order to expand the user population more advertising and training efforts are required. Therefore, how to sell the tool might be an area for further study.
- <u>LISI Data Accuracy Assurance</u>: Garbage in and garbage out, the LISI output for the interoperability assessment and improvement are only as good as the data. In addition to having the knowledgeable person input the data, the possible mechanisms to coordinate and trigger the updates of database will be an added value to the LISI system and should be explored.

- LISI Continuing Evolution and Enhancement: LISI has come a long way to today's pilot assessments. It has evolved since its inception in 1993. Each evolution refines and enhances the LISI system and should be continued. Further study should be continued to assess the current LISI system and application and to recommend ways for improvement.
- Validation of LISI Usefulness Based on GAO Recommendations: GAO identified several weaknesses in DOD's process for certifying C4I systems' interoperability in its March 1998 report. It also endorsed LISI initiative in the report and recommended that system developers use LISI for assessing interoperability, determining capabilities needed, and determining the degree of interoperability needed between C4I and other systems. After the LISI implementation becomes C4I system wide, a further study should be conducted to show if and how LISI can improve the deficiencies identified in the GAO report.

In its final report of the Pilot Assessment of LISI Using Components of the ABCS, ASEO and HTIO anticipated that a "joint' interoperability assessment would be feasible in early FY00. As of this writing, the anticipation was overly optimistic, therefore, the findings from the Pilot Assessment of ABCS, which are only part of the C4I systems, were used to derive the conclusions. Further study should be conducted as soon as the "joint" interoperability assessment is made possible and all the C4I systems are included in the database.

Interoperability is an ideal condition that can be approached but never totally achieved because of the dynamic nature of military operations, system acquisition, and technology improvements. Therefore, the continuing of LISI evolution and enhancements is unavoidable. It is my sincere desire that the above-recommended areas be further studied, ways to enhance LISI system can be implemented, improvements on C4I system interoperability can be realized on a continuing basis, and collectively, we can achieve the information Superiority envision by Joint Vision 2010.

APPENDIX A – ACRONYMS AND ABBREVIATIONS

A&T	Acquisition and Technology
ABCS	Army Battle Command and Control Systems
AEGIS	Airborne Early Warning/Ground Environment Integration Segment
AFTDS	Advanced field Artillery Tactical Data System
AIMIS	Army Interoperability Management Information System
AMC	Army Materiel Command
AMDWS	Air and Missile Defense Workstation
ASAS	All Source Analysis System
ASD	Assistant Secretary of Defense
ASEO	Army System Engineering Office
AWG	Architectures Working Group
BCC	Biological Chemical Command
BMDO	Ballistic Missile Defense Office
CCB	Configuration Control Board
CDG	Competitive Development Group
CECOM	Communications and Electronics Command
CIPO	C4ISR Interoperability Program Office
COE	Common Operating Environment
CSSCS	Combat Service Support Control System
C2	Command and Control
C3I	Command, Control, Communications, and Intelligence
C3S	Command, Control, and Communications Systems
C4I	Command, Control, Communications, Computers, and Intelligence
C4ISP	C4I Support Plan
C4ISR	C4I Surveillance and Reconnaissance
DA	Department of Army
DAMO	DA Military Office (Office of Deputy Chief of Staff for Operations)
DCSOPS	Deputy Chief of staff for Operations
DII	Defense Information Infrastructure
DISA	Defense Information Systems Agency
DOD	Department of Defense
DOI	Directorate of Integration
DTSS	Digital Topographic Support System
ESC	Electronic Systems Center
FBCB2	Force XXI Battle Command – Brigade and Below
FDD	First Digital Division

GAO	General Accounting Office
GCSS-A	Global Combat Support System - Army
HQDA	Headquarters, Department of the Army
HTIO	Horizontal Technology Integration Office
HTML	Hyper Text Markup Language
IAP	Integrated Architectures Panel
I&RTS	Integration and Runtime Standards
ICD	Interface Control Document
IF	Intelligence Fusion
IMETS	Integrated Meteorological System
IOC	Initial Operational Capability
IP	Internet Protocol
ISC	Intelligence Systems Council
ISO	International Standard Organization
ISYSCON	Integrated Systems Control
IT	Information Technology
	Internet Protocol
ITF	Integration Task Force
ITMRA	Information Technology Management Reform Act
JBC	Joint Battle Center
JCPAT	Joint C4 Program Assessment Tools
JITC	Joint Interoperability Test Command
JS	Joint Staff
JTA	Joint Technical Architecture
JTF	Joint Task Force
JULLS	Joint Universal Lessons Learned Systems
JWICS	Joint Warfare Intelligence Center
LISI	Levels of Information Systems Interoperability
MCS	Maneuver Control System
MARCORSYSCOM	Marine Corps Systems Command
MNS	Mission Needs Statement
NIPRNET	Non-Secure Internet Protocol Network
ORD	Operational Requirements Document
OSD	Office of the Secretary of Defense
OSI	Open Systems Interconnection

PAID	Procedures, Applications, Infrastructure, and Data
PEO	Program Executive Office
PM	Program Manager
PMO	Program management Office
QDR	Quadrennial Defense Review
RMA	Revolution in Military Affairs
ROM	Rough Order of Magnitude
SA	System Administrator
SHADE	Shared Data Environment
SIPRNET	Secure Internet Protocol Network
SM	System Manager
SoS	System-Of-Systems
STAMIS	Standard Army Management Information System
TACOM	Tank Automotive Command
TAIS	Tactical Airspace Integration System
TBMCS	Theatre Maritime Battle Management Core System
TCP	Transmission Control Protocol
TEMP	Test and Evaluation Master Plan
TM	Theater Missile
UCAO	Unified Cryptology Architecture Office
USD	Under Secretary of Defense
USMTF	US Message Text Format
VCJCS	Vice Chairman of the Joint Chiefs of Staff

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